NATIONAL COMMISSION ON SPACE REPORT

HEARING

BEFORE THE

SUBCOMMITTEE ON
SPACE SCIENCE AND APPLICATIONS

OF THE

COMMITTEE ON
SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

NINETY-NINTH CONGRESS

SECOND SESSION

JULY 22, 1986

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*Ranking Republican Member.
**Serving on Committee on the Budget for 99th Congress.

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NATIONAL COMMISSION ON SPACE REPORT

TUESDAY, JULY 22, 1986

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS,
Washington, DC.

The subcommittee met, pursuant to call, at 10:05 a.m., in room 2318, Rayburn House Office Building, Hon. Bill Nelson (chairman of the subcommittee) presiding.

Mr. NELSON. Good morning. We have a number of other committee markups that are going simultaneously, so a number of our members are going to be late in arriving.

Dr. Paine, we are delighted to have you here today. It is an honor that you would come and present this report to the Congress. We understand that you are going to the President this afternoon to formally present your report to him. I have seen this report, read parts of it. I think it is a marvelous, job.

So today we want, as the committee, to formally receive a review from you and your Commission on this report entitled Pioneering the Space Frontier.

For review, this Commission was established by the Congress in 1984 to formulate a long-range agenda for U.S. civilian space activity, so we could identify long-range goals, opportunities, and policy options.

Today we want to try to obtain an understanding of the process which the Commission followed to arrive at its conclusions, what those conclusions are, as well as what the alternatives were that were considered, and some that were considered and discarded.

We want to understand what steps must be taken by both Government and industry to give us the necessary vision of this country's future in space so that we can maintain America's preeminent role in space.

Now, it is a time of budget constraint—and that is not going to end with this year. Those constraints are going to be upon us in the future. So it is very important for us to be able to understand what priorities should be set as we look to the future. And as you make your recommendations to us we would like you to keep that in mind.

We want to look at how reasonable the objectives are which you have set, and how reasonable are the financial projections requested to achieve them.

We certainly welcome these witnesses today to assist this subcommittee in its deliberations. We are just delighted to have Dr. Paine, the Chairman of the Commission.

I had the privilege of having Dr. Paine and his Executive Director, Ms. Smith, accompany this committee as we went to Moscow last October. We visited Soviet facilities for the first time since our Apollo astronauts in the ASTP mission had trained there. We were fortunate to have two of our three Apollo astronauts—Tom Stafford and Deke Slayton—also along with us, and had a marvelous 10-year reunion with the cosmonauts there. That is a special fraternity, and it was obvious as we saw them joining together with their spouses in that 10-year reunion just what a special fraternity that is.

We are delighted to have Dr. Wilkening, the Vice Chairman, and Commissioners Dr. Field, Dr. Kerrebrock and Dr. Sullivan.

Later in this hearing we will hear from Dr. Sagan, Director of Planetary Studies at Cornell, and we are looking forward to your testimony, Dr. Sagan.

We invited Dr. Jack Townsend of the Space Applications Board, and Dr. Tom Donahue of the Space Science Board, but they are unable to be here today.

We will submit for the record the opening statements of Mr. Lujan, and Mr. Brown.

[See appendix.]

Mr. NELSON. Dr. Paine, we will start with you and as we get on into it we are getting some of these members out of the markup of other bills that are proceeding. I know of two markups that are going simultaneously at this point.

Please proceed.

STATEMENTS OF DR. THOMAS O. PAINE, CHAIRMAN, NATIONAL COMMISSION ON SPACE; DR. LAUREL L. WILKENING, VICE CHAIRMAN; DR. GEORGE B. FIELD, MEMBER; DR. JACK L. KERREBROCK, MEMBER, AND DR. KATHRYN D. SULLIVAN, MEMBER

Dr. PAINE. Thank you very much, Mr. Chairman, and with your permission, I will——

Mr. NELSON. You had better flick that microphone on.

Dr. PAINE. Thank you very much, Mr. Chairman, and with your permission, I will put an opening statement in the record and just very briefly summarize. The reason for our being here, of course, for us, is a very joyous occasion. It has been a very long and arduous year in many ways. But at the same time, it's been a very satisfying year and I think we have had an opportunity to look into the future and to bring to this committee the results of a number of deliberations.

In preparing the final report, which we are formally presenting to you today, we took testimony from witnesses all across the country, from Seattle in the north, to Florida in the south, Hawaii in the west, Boston in the east. We talked to people from all walks of life in open microphone forums. And from this I think we've got a new understanding of the feeling that many Americans have for the space program. Of course, in the middle of our deliberations we had the tragedy of the loss of the *Challenger* and its crew. And I think if anything, this brought home to us with even greater poignancy, but also greater force, the tremendously important role that the space program plays in the life of this country.

We also assembled expert witnesses from the American Institute of Aeronautics and Astronautics and asked them to use their committee structure to give us a projection of where space technology would be going in the next 50 years.

We also drew on their capability to host a special meeting to discuss the very difficult area of space commercialization in which we had both young entrepreneurs and representatives of the large established companies, all examining the question: Where is the economic future in space, both short-range and long-range?

In addition to this, since we were looking so far into the future, we assembled a gaggle, I suppose you might call—I don't know what you call a group of futurists—but we assembled them to try to get the different insights that people might have on the 21st century America environment. This is a very difficult subject and we wanted to get the broadest possible viewpoints. In many ways we felt it was like the classic example of the blind man describing the elephant—each person sees a different facet. And from all of this we tried to assemble what 21st century America would be like. And then answer your question: What would be the best possible space program to further the broader goals of 21st century America?

In addition, we traveled overseas, very kindly at your invitation, to talk to our Soviet opposite numbers. We also discussed in Paris with the European Space Agency their plans for the future. Others of us attended international meetings in Stockholm, Switzerland, Germany, and Italy. We had presentations from the European Space Agency. We had all of the major aerospace contractors come in and give us their viewpoints. We had many members of academia. And we also were very privileged at Dr. Tom Donahue's invitation, to go to Woods Hole while his summer group was having their study of the future of space science and, indeed, American science, moving into the next century to make sure that we understood what the mainstream of scientific thought was, the opportunities, the programs that should be put into place.

So, it was from these inputs that we then had our series of meetings. And I must tell you that the basic approach that we took was that the report's contents would reflect the 15 Commissioners' viewpoints. All 15 have signed it. And we laid it out as a ground rule that we would not try to second guess what this committee might wish to receive, might find palatable, what you, Mr. Chairman, might—might wish us to say. But that, rather, we would try to take a look at the state of this Nation in the year 1985 and 1986; where we thought we were going for the next 50 years; where we thought the rest of the world was going; what the status of the—of the technology and the economies would be; and particularly, then, of the structure of the inner solar system around us and what opportunities there might be.

And it was from a distillation of all of these considerations that we then, in a series of meetings, hammered out one by one the various points that you see mentioned in our report.

I believe it is fair to say that when you are considering the question of American leadership in space, which you mentioned in your opening remarks, that this implies not only the level of effort and the direction of the United States, but it also implies that we know something about where other nations are going.

And I think perhaps, again, with your permission, Mr. Chairman, it might be relevant to put in the record the article from this morning's New York Times on the future thrust of the Soviet space program, which I think is a reasonably broad survey, and certainly is in accordance with the things which we found during our visit and in discussions since.

Mr. NELSON. Thank you for that recommendation. It will be done.

[The news article follows:]

TUESDAY, JULY 22, 1986

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Science Times

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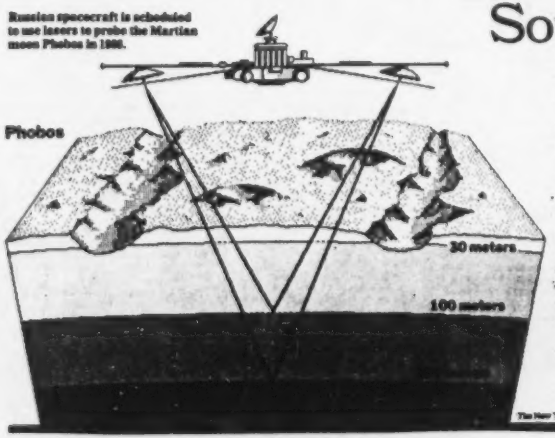

Russian spacecraft is scheduled to use lasers to probe the Martian moon Phobos in 1988.

Soviet Details Ambitious Space Plans

Already active program expanding with manned and unmanned projects.

By WILLIAM J. BROAD

Special to The New York Times

MOSCOW, July 20 — While the American space program tries to recover from setbacks that have left dozens of missions on hold and all major rocket systems grounded, the Soviet Union is pressing ahead in a vigorous bid for pre-eminence in the heavens.

Already this year the Soviet Union has conducted more than 40 major launchings, established a large new space station and achieved a space-age first by ferrying astronauts between stations in orbit. Last week they moved a step closer to their goal of a permanent manned presence in space by completing a four-month mission.

And in interviews last week Soviet space planners, scientists and experts outlined an ambitious series of ventures meant to stretch well into the next century.

In the future, Soviet engineers hope to inaugurate a new generation of rockets, an advanced space shuttle and the first large space-based radio telescope. And Soviet planetary scientists, fresh from celebrating a successful flight past Halley's Comet, are planning a series of unmanned probes toward Venus, the Martian moon Phobos, and beyond.

Early in the next century they hope to send a manned expedition to Mars; scientists and experts here say the Soviet program is preparing for the voyage.

"Manned missions to Mars are very interesting and exciting," said Dr. Roald Z. Sagdeyev, director of the Space Research Institute of the Soviet Academy of Sciences, "but first we need unmanned precursors such as landings on Mars to bring back samples."

"Today we do research in space," said Dr. Liya L. Regel, head of the institute's materials science laboratory. "In a few years it will be factories."

"The longer man is in space, the more he learns, the cheaper his stay and the more he can do," said Dr. Alexei S. Yeliseyev, a veteran Soviet astronaut who now heads the Moscow High Technical College.

Despite the extent of Soviet projects and ambitions, Western experts say the American program is still ahead in many respects, having a better technological base and a potential for greater achievement. Still, they add, the Soviet Union has come a long way by virtue of hard work and steady application.

"It's a classic case of the tortoise and

Continued on Page C3

Russians Detail Big Space Projects

Continued From Page C1

the here," said Nicholas L. Johnson, author of "Soviet Year in Space," published annually by Teledyne Brown Engineering in Colorado Springs, Colo. "Little by little, they're embarking on big things. And they're being much more open about it. In the past we wouldn't know about a Venus mission until it took off from the pad."

Nowhere is the openness more visible than in the Soviet man-in-space program, whose launchings and landings have recently been televised live and whose astronauts have begun to write articles for the Western press. In the July 27 issue of Parade magazine, for example, Vladimir Dzhanibekov, an astronaut, recounts how he helped save the derelict Salyut 7 space station last year after it suffered an electrical failure.

Soviet astronauts beamed a broadcast over state television last week as they prepared to descend from their new space station Mir, whose name means "peace" in Russian. "It's sad for us to leave," said Vladimir A. Solovyov, 39 years old, a flight engineer.

Indeed, Mir is a palace compared to the older Salyut space stations. Inside the older 40-foot Salyut 7, Soviet astronauts lived and worked in the same cramped area. But inside Mir, which is 56 feet long, they have separate living quarters, a common area for eating and exercise, and a control room. Mir has six docking ports and spaces for a cluster of separate work areas and laboratory modules. "They will be as large as Mir itself," said Dr. Yelisseyev, who in 1971 docked with the first Salyut station.

Over the years Soviet astronauts have steadily increased the time they spend in space stations. According to Mr. Johnson, Salyut 6 was occupied 16 percent of the time, Salyut 6 was occupied 38 percent of the time, and Salyut 7 has been occupied 56 percent of its time in orbit about the earth. In 1984 one team of Soviet astronauts stayed in space for eight months, a record.

What do they do there? According to Soviet space officials, the main tasks involve astronomy, geophysics, medicine, materials science, atmospheric studies, experiments in plant growth, tests of welding and other construction techniques, and earth photography for use in monitoring resources and making maps. The astronauts who just returned to earth took pictures of the damaged Chernobyl reactor and, in a simultaneous exercise with an unmanned Cosmos satellite, of East German territory.

Soviet astronauts working in space already make crystals for electronics and drugs for use on earth. In the future they hope to produce goods for their own use. "Today we cannot make transistors," in space, said Dr. Regel. "But the solution to this problem is very near for us."

When problems like this are solved, astronauts will be able to build and repair equipment on voyages into deep space.

Soviet scientists also hope to develop ways to recycle air, waste and water so that astronauts can be biologically self-sufficient. Today supplies are regularly sent aloft to astronauts on unmanned Progress cargo ships. In the future, on long trips to Mars, resupply will be impossible.

Already Soviet scientists have recycled some water vapor and perspiration in space stations, and they are experimenting with the use of human wastes to grow grains and vegetables. At Krasnoyarsk in Siberia researchers have designed "Bios," a tightly sealed laboratory in which human subjects live, work and sleep. Recently two volunteers spent five months sealed in Bios, having been issued only one-fifth the amount of food normally needed for that period. The remaining food, as well as air and water, was produced by their own efforts.

In addition to performing specific tasks in space, Soviet astronauts watch for the unexpected. "At first cosmonauts think they see a lot," said Dr. Yelisseyev, "but in two months they begin to notice much more. They learn to tell ordinary phenomena from those that are extraordinary."

Soviet astronauts may make other types of observations from space. "Soviet Military Power," a booklet issued annually by the Pentagon, lists many possible military missions, and says Soviet astronauts have "probably" conducted military exercises and experiments in space, an assertion Soviet officials vigorously deny.

"No," said Dr. Yelisseyev, "we have never planned any military programs for a manned mission. In particular, our foreign visitors come and go from the station, and it's easy for them to observe that there are no military goals." To date, the Soviet Union has had 11 space guests and has scheduled future flights for French and Syrian astronauts.

As the Soviet man-in-space program has become more open, more information has become available on some areas of rocketry. The giant 200-foot Proton booster, the workhorse of the Soviet fleet, used to be shrouded in secrecy, its exact power and specifications known only to Soviet scientists. Now, however, the Russians are marketing its services to the West, distributing manuals describing features customers would need to know about to prepare payloads.

But new developments are still largely off limits. Soviet officials admit work is under way but add few details. According to the Pentagon, a Soviet space shuttle could be launched by late 1986 or 1987. Soviet officials will not comment on this estimate. But echoing the current consensus in United States, they say that future re-useable Soviet spacecraft such as winged shuttles would complement rather than replace expendable rockets.

"We consider expendables an essential element of our space transportation system," said Dr. Segdeyev of the Space Research Institute. "I personally doubt that re-useable transports will ever replace them."

Western experts say new rockets may well be the first in the Soviet Union to use cryogenic, supercold fuels such as liquid hydrogen. "Cryogenic fuels are more efficient," said Marcia S. Smith, president of the American Astronautical Society. "You get more bang for your buck. We've had them for 30 years. Even the Chinese have them."

On the other hand, the Soviet scientists pride themselves on technological conservatism. "New technology always brings some risk," Dr. Yelisseyev said. The engines they use now may not be the most efficient, but their rockets are very large and reliable. Last year the Soviet Union conducted 98 major launchings, as against 17 for the United States, three for the European Space Agency, two for Japan and one for the People's Republic of China. About 70 percent of

moon of Mars, in 1988. Among the 30 experiments on board will be a laser whose beam is meant to penetrate the surface of Phobos repeatedly, and another instrument to analyse the resulting debris for information about Phobos's chemical composition. This experiment is to be done as the spacecraft glides above the moon at an altitude of some 160 feet.

"Nothing like this has ever been done before," said Dr. Georgy Managazi director of the active experiment laboratory at the Space Research Institute. "Some people say it's impossible."

The experiment may help settle an old dispute over the origin of Phobos. Some astronomers believe the moon is an asteroid caught in the gravitational grip of Mars and some say it is a naturally formed moon.

Around 1990, the Soviet Union plans to loft the first large radiotelescope into space. "It will have a resolution 10 times better than anything now," said Dr. Nikolai K. Kardashev, deputy director of the Space Research Institute. With a dish 32 feet in diameter the orbiting antenna, the Space Very Long Baseline Interferometer, is to be used in conjunction with antennas on the ground to electronically create a radio telescope many thousands of miles in diameter.

"The most interesting use will be searching for quasars," said Dr. Kardashev. These powerful stellar objects at the edge of the known universe are believed to be produced by black holes, which scientists believe are stars so dense that even light cannot escape their gravitational grip.

Later in the 1990's the Soviet Union plans to send unmanned missions to Venus, the moon, a comet and possibly far beyond. "There's a possibility of probes to the giant planets, to Saturn and Jupiter," said Dr. Sagdeyev, adding that such missions would be made only if they were unlike ones already undertaken by the American space program.

Indeed, international cooperation of one sort or another has lately become the vogue in the Soviet space program. The Soviet Vega mission to Halley's Comet was aided by more than a dozen countries, including the United States, some providing the advanced instruments that made the mission worthwhile. So, too, the Phobos experiments are to be cooperative ventures with 11 countries, including Austria, Finland, France, Switzerland and West Germany.

According to Western experts, the Soviet space program tends to move ahead by doing what it does best and by getting help from abroad, sometimes with the aid of spies or smugglers, with everything else. Its main strengths lie in rocketry and long-duration manned space flight, its main weaknesses in advanced instrumentation and the computer chips that bring delicate space probes to life.

Despite such limitations, and with a little help from its friends, the Soviet space program, manned and unmanned, is forging ahead at a remarkable pace.

Vladimir A. Solovyov, left, with Col. Leonid D. Kizim after returning to Earth last Wednesday after 125 days.

Dr. PAINE. What I would like to suggest now before proceeding with our meeting is that I would like to have statements from Dr. Laurel Wilkening, Dr. George Field, and Dr. Jack Kerrebrock, but perhaps before we proceed to that, if it is agreeable to you, we might take the next 30 minutes to review the television 30-minute presentation of our report.

In discussions with this committee, we proposed that in addition to the basic what we call our Gutenberg version of our final report, which was published by Bantam Books, and we have made it broadly available across the country, that it would be also a good idea to reach the even larger audience of television. And so we have put together a 30-minute documentary which also presents the results of our committee report.

And if this is agreeable to you, Mr. Chairman, I would suggest that now might be a good time to look at our 30-minute television report.

Mr. NELSON. All right, Dr. Paine, we will certainly do that. Let's proceed with the video.

[Video presentation.]

Mr. NELSON. Thank you, Dr. Paine. Excellent presentation. I think it's very smart of the Commission to put that in video form as well as this marvelous publication that you put together here. Your space art is terrific in illustrating your words here.

Please proceed.

Dr. PAINE. Well, Mr. Chairman, I'd like to point out to this committee that the art in this report was not prepared at any cost to the American taxpayer, but was contributed by Bantam Books in return for the opportunity to publish and distribute our report.

I might also mention that the—one of the basic questions which the Commission addressed was whether or not we should have a program that had specific goals out into the future. And it was our conclusion that particularly in a time of financial austerity that long-range planning, doing things once, doing them right, knowing how they would fit into a program, is very likely the most economical way to proceed as well as the way to proceed and get the best results for the Nation.

I think that the question of rebuilding NASA in the wake of the *Challenger* tragedy very largely comes down to this opportunity that we have to reassess the future direction and pace of the American space program. And in that connection, we think that the wisdom of this committee in undertaking to have a long-range look at the future has been borne out.

Questions have been raised about the timing, why should we be coming out with a long-range look at space when we have a number of short-range problems of how do we recover from the *Challenger* accident.

But in my view, this is an excellent time for this committee to pause, as NASA is pausing, to regroup and rebuild, and to ask the question: Where are we going in space? I think the worst thing that could happen to the American space program at this point would be to have an aimless lack of goal, a lack of crisp decision, that we need to decide what we are going to do about replacing the *Challenger*. We need to decide how it is going to be handled in a budgetary way. We need to decide what is going to be our launch

capability of the future; what mix of manned and unmanned capability we need. We need to phase this into a budget in such a way that we don't have peaks and valleys, but rather, a sustained effort.

And I think that without high level vision and purpose and leadership there essentially can be no opportunity for America in space. And so we commend this committee for having asked us to prepare this report. It's been a great labor of love, I assure you, to try to come up with a broad program that will be balanced, that will be based on an accurate view of the future.

[The prepared statement of Dr. Paine follows:]

Chairman
Dr. Thomas O. Paine
Vice Chairman
Dr. Laurel L. Wilkening
Dr. Luis W. Alvarez
Mr. Neil A. Armstrong
Dr. Paul J. Coleman
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NATIONAL COMMISSION ON SPACE
400 L'Enfant Plaza East, SW Suite 3212
Washington, DC 20024
Telephone: (202) 453-8685

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July 22, 1986

AMERICA'S FUTURE IN SPACE

Final Report of the National Commission on Space

SUBCOMMITTEE ON SPACE SCIENCE & APPLICATIONS
COMMITTEE ON SCIENCE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

Statement by:

THOMAS O. PAINE, CHAIRMAN
National Commission on Space

AMERICA'S FUTURE IN SPACE

Final Report of the National Commission on Space

Thomas O. Paine, Chairman

July 22, 1986

As NASA pauses to rebuild in the wake of the Challenger disaster, it is time for a thoughtful, high-level review of America's future in space. Throughout this country and, indeed, around the world, people are looking to the President and the Congress to reaffirm the rationale, direction and pace of our civilian space program. NASA urgently needs a new sense of purpose and long-range objectives. Where is our space program headed? What goals lie beyond the Space Station and low Earth orbit? What future space agenda will best further the broader objectives of 21st-century America? What are humanity's overarching goals in space?

In 1984 the National Commission on Space was charged by the Congress and appointed by the President to address these questions. We have looked 50 years into the future, and are proposing bold civilian space goals for the next 20 years. We have completed our work and submitted to your staff and to the White House staff our final report, *Pioneering the Space Frontier*. To facilitate public discussion of the complex issues involved, we are making the report widely available at bookstores across the country through Bantam Books. This "Gutenberg" version has been supplemented by a 30-minute TV tape report that is also available to the media and the public; we are holding its world premier in our hearings today.

In conducting the studies leading to the preparation of its final report, the Commission took testimony from expert witnesses in meetings across the country, received opinions from hundreds of citizens in public forums, commissioned studies of future technological progress by the American Institute of Aeronautics and Astronautics (AIAA), convened a meeting of futurists to consider 21st-century America, sponsored an AIAA symposium on space commercialization, initiated a review of two centuries of U.S. and world economic growth, and solicited suggestions through periodicals, direct mail and electronic bulletin boards. In Paris and Bonn a few of us reviewed the European Space Agency's new interest in commercial enterprise and manned space flight. In Moscow we discussed opportunities for joint Soviet-American space missions, and the new Soviet concentration on Mars, including their scheduled 1988 robotic mission to explore the Martian moons, Phobos and Deimos. From all of these activities a vision of the next 50 years in space emerged that provided the basis for our Commission's conclusions and recommendations.

We see advancing space technologies freeing mankind to move outward from Earth as a species destined to expand to new worlds. America's pioneering heritage, technological preeminence and economic strength make it fitting that this Nation lead mankind's movement into the Solar System. As formerly on the western frontier, now on the space frontier government should support initial exploration and science, advance critical technologies, and provide the basic transportation infrastructure, legal framework and civil administration required to open broad access to new lands. Such a future-oriented investment by the American people will again generate in value many times its cost, to the benefit of future generations.

With this rationale in mind, the Commission proposes this broad, long-range, pioneering mission for the American space program:

To lead the exploration and development of the space frontier, advancing science, technology and enterprise, and building institutions and systems that make accessible vast new resources and support human settlements beyond Earth orbit, from the highlands of the Moon to the plains of Mars.

To accomplish this mission, three mutually-supportive thrusts are outlined:

- Advancing scientific understanding of Planet Earth, the Solar System and the Universe;
- Exploring, prospecting and settling the Solar System; and
- Stimulating space enterprise.

To support these, two additional thrusts are essential:

- Advancing technologies across a broad spectrum to enhance capabilities and lower costs; and
- Creating systems and institutions to provide safe, reliable, low-cost access to the space frontier.

These thrusts will involve a creative partnership of government, academia and industry of the type which has proven so effective in our history. Our most urgent need, and the greatest contribution NASA can make by the year 2000, is to lower by an order of magnitude the cost of transporting cargo and passengers into orbit and beyond throughout the inner Solar System. Critical technologies include dual-cycle rocket engines, aerospace plane systems, artificial intelligence, tethers, advanced materials and aerobraking systems. To "live off the land" on the space frontier, NASA must vigorously pursue two new technologies: robotic processing of extraterrestrial materials, and closed-ecology biospheres to recycle air, water and food. All of these technologies have major implications for 21st-century America's economic strength and security.

Our proposed 20-year civilian space goals include a "Highway to Space" and "Bridge Between Worlds." These will support initial astronaut outposts on the Moon by 2005. A decade later spaceships with artificial gravity can begin to cycle between the orbits of Earth and Mars to open continuous human access to the rich resources and spectacular landscapes of Mars. The Commission's proposed new space agenda for America is paced to maintain NASA's budget at less than half the peak percentage of national expenditures reached during the Apollo years. The expected benefits to America and the world will greatly outweigh the costs. Major international participation is proposed in a program that the Commission is confident will attract the best minds of the 21st century.

Our report recognizes that the final decision will be made by the American people through the Congress and the Administration. The Commission report is therefore not a prophesy, but a description of what the United States can make happen through vigorous leadership in pioneering the space frontier.

More than a new launch vehicle, more than a replacement orbiter or space station -- even more than an increased budget -- **NASA needs a new sense of purpose and new long-range goals.** Aimlessness and indecision will devastate America's civilian space program. Crucial decisions about future launch vehicles, shuttle orbiters, the space station, space science and technology programs, and budget levels must be addressed in a timely fashion. Without high-level vision, purpose and leadership, there can be no future for America in space.

The exploration of the Moon and Mars with robotic precursors followed by continuing human presence, is a sound, long-range goal. It would restore NASA's vigor and attract top people to the space program. Such a goal would define a purpose for the space station, so that its requirements, design and schedule could be sensibly planned. It would provide a basis for international contribution and participation. It would provide a focus for planetary exploration and guide supporting missions of science and technology. It would support the development of a logical launch vehicle plan, involving the private sector, with the best mix of piloted and automatic vehicles. It would reorient our space program to serve America's broader national interests and security. If the United States and the Soviet Union can find ways to join together to lead humankind to new worlds, we can develop new opportunities for harmony and peace on Earth. Creating a bridge to the Moon and Mars will give human space flight its greatest role: exploring the unknown to open new worlds for future generations.

Thomas O. Paine
Chairman

Dr. PAINE. And before I ask Dr. Wilkening for her comments, I would like to just restate something we said before, and that is that our report is not a prediction of the future; but rather, we believe it to be an accurate statement of what America can make happen if indeed it is this Nation's decision to continue to provide leadership in space.

Mr. NELSON. As a matter of fact, I think one of the comments that you shared with me that is most revealing, and why don't you state it for the record—the one about that this report could have been written 10 years ago or 10 years in the future.

Dr. PAINE. Well, Mr. Chairman, I think that as we look at this report, indeed, it could have been written 10 or 15 years ago. I think that if we take another look at this Nation's future in space 10 or 15 years from now, we would come to conclusions very similar to that.

I think I must also point out that this report could equally well have been written in Moscow or Beijing. The standard state of world technology tends to be within a decade across these national boundaries—really, it's world technology, not any one nation's. And I think also that the structure of the inner solar system is just the same. Mars today is 37½ million miles away from Washington. It's also 37½ million miles distant from Moscow.

Mr. NELSON. And that underscores your point that there's going to be a moon base and a Martian base. It's just a question of what language is going to be spoken there.

Dr. PAINE. Well, that's Dr. Wilkening's comment, and perhaps we should ask her to——

Mr. NELSON. Yes, let's use that as the opening. Dr. Wilkening?

Dr. WILKENING. Thank you, Mr. Chairman, and ladies and gentlemen. Thank you for the opportunity to participate in your discussion of the future of the civilian space program today.

In our review of the civilian space program, our Commission identified three areas in which the U.S. program could expect to provide world leadership and thereby obtain substantial return for investing in those areas. They were: science, exploration, and enterprise. Today I will direct my remarks principally to exploration—exploring, prospecting, and settling the inner solar system.

We are poised on the boundary of the space frontier. Our scouts, mostly robotic, have traveled far and wide in this new territory—the solar system. Regular human expeditions are now visiting the first outposts in Earth's orbit.

The exploration of the inner solar system, that is, our planetary neighbors—Venus, Mars, and the Moon—has gone far beyond mere reconnaissance. In fact, a human geologist has even visited one of our planetary neighbors—the Moon—and conducted scientific studies there that could be characterized as prospecting.

In the case of Mars, very sophisticated sets of robotic spacecraft, the Mariners and the Vikings, probed its atmosphere and surface and provided detailed photography of many interesting areas of the surface.

The Soviet Union, as well as the United States, in separate missions, have provided substantial information about Venus and its atmosphere and surface.

The work of these frontier pathfinders has been completed in a sense and the inner solar system is now ready for the prospectors and the entrepreneurs. The question before us is what will the role of our country be?

We have three choices: leading, following, or dropping out. As an American, I think you can guess what my preference among those three is. It's certainly not the last.

In contrast to the first decade and a half of the space age, when the United States was the acknowledged leader in space science and exploration, the situation in contrast is quite different now. There is no longer a lack of activity by other nations. If the United States is going to lead, it cannot set its own leisurely pace.

I have been saying these words for about a year now, but I must say they only have come really home to me in the last 6 months. The first time came when a delegation of Japanese industrialists came to our university to visit our NASA Center for Excellence in Separation Science.

These were industrialists from heavy industry and electronics, chemicals, those kind of things. And I asked the delegation leader why they were doing this. I said, is your intention to stimulate activity in your private sector, such as the Europeans do by placing aerospace projects in various industries. And he said no. Their interest was really space-based manufacturing. And when this gentleman stood there and told this to me, I mean, I had to believe him. I couldn't say, well, you know, you're really kidding, aren't you? So it's quite serious.

I also just lost a member of my staff to Aeritalia, which is the—one of the major space industry's—aerospace industries in Italy. And she happened to have a nice background in geology, science writing and Italian. She was a member of my direct staff—not a university faculty member. But it's clear that there's a lot going on in other countries.

And this is well recognized also in the science area. I know you are all familiar with the fact that this year saw the encounter of Comet Halley by spacecraft from countries represented by the European Space Agency, the Soviet Union, and Japan, and not the United States. And we all know that the European Space Agency has a long-range plan for its planetary exploration program that involves returning a sample from a comet.

The Soviet Union has announced a series of increasingly ambitious missions focused on Mars. And I didn't read the New York Times today so I don't know what it said. I read the wrong newspaper, I guess—the Washington Post. But from what I know, they are ultimately going to do a landing mission in the next decade that will involve a hopper on Phobos—one of the moons of Mars—and it will hop around making chemical assays there. Probably will turn up some very interesting results.

On the other hand, the most recent planetary mission launched by this country was Pioneer Venus in 1978. And while NASA has a plan for missions to continue our leadership in planetary exploration, as you all know, planetary exploration is grounded due to the lack of availability of a suitable deep-space launch vehicle—due to the cancellation of the Centaur upper stage.

The Galileo mission, which was the first planetary mission to be mounted by this country since 1978, was ready for launch this year. It is grounded indefinitely.

Far from taking the steps that are necessary to bring about a major enhancement of our activities, in the next decade—not even this decade, our country seems to be doing just the opposite. No new science missions are being considered by NASA at this time. No plan for developing deep space launch capabilities is emerging. And tremendous uncertainty surrounds the funding of the replacement of the *Challenger* space shuttle.

Rather than planning for continued leadership in space science and exploration by the United States, a lack of commitment by this Nation to the civilian space program is resulting in rapid erosion of our leadership in the space science programs—from life sciences to astrophysics.

The Commission strongly believes that space science and exploration are too important to this country to be abandoned. But, by default, we are abandoning them.

What should we be doing? The National Academy of Sciences and various scientific advisory committees to NASA have carefully and thoughtfully designed plans for space sciences in the future. The Commission reviewed those plans and endorsed them.

Now, less detailed planning has occurred in those areas of the space program that relate to prospecting, resource development, and industrialization—the next step.

We know from our scientific studies that Venus is a very inhospitable planet. The surface is high—the surface temperature is high enough to melt lead. It's not a place that we envision a lot of human activity or even robotic activity.

On the other hand, the Moon and Mars, while providing their own interesting and difficult environments, nevertheless, hold out the prospect that extended scientific exploration and eventual commercial activity could take place on both of these objects. And that's why throughout the video tape and in our report we have focused on those two objects, through scientifically based reasons—common sense. For this reason, our plans are focused that way.

And we have found that in the near-term there's a considerable overlap between the activities that are planned for scientific exploration in those areas and the things that would lead to the next step—the detailed exploration, the prospecting, industrialization, and settling.

For example, we recognize for both scientific reasons and for prospecting that a lunar polar prospector mission to examine the entire surface of the Moon from low orbit is a high priority.

Probe missions to do subsurface analyses of various lunar surface regions are also a priority.

And Earth and space-based searches for readily accessible asteroids, telescopic characterization of them, and eventual prospector missions to them are very important to our future activities in the Earth space.

A similar series of robotic prospecting missions to Mars and its moons could also be laid out. It is clear from many different aspects that these studies would culminate in the return of samples

from various locales of scientific interest and those showing promise for future activity on Mars.

We did make a big assumption. We assumed that exploration and prospecting would lead to space-based commerce. And as economic activity develops in the inner solar system we also assumed that humans would follow. We have based this assumption on our analogy with past exploration and development such as that of the western frontier of our own country where people followed the economic activity associated with mining and farming on the Pacific coast.

This country needs a national commitment to a civilian space program. When I looked at the video tape this morning it seemed technologically so near and politically so far. And the bridge between those is commitment. This commitment must focus on specific goals. On the assumptions that I've previously outlined, we recommended a 50-year goal of establishing bases on the Moon and Mars. But as Dr. Paine described in the video tape, we see this as a natural evolution. We don't recommend a one-shot space spectacle. It is the difference between Scott's and Amundsen's dashes to the South Pole and building the Alaskan Pipeline. The time has come for humans to move into space with the expectation of living and working there.

And, Chairman Nelson, the only question is: What language will they be speaking?

Thank you.

[The prepared statement of Dr. Wilkening follows:]

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VICE CHAIRMAN
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Dr. Luis W. Alvarez
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490 L'Enfant Plaza East, SW Suite 3212
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Final Report of the National Commission on Space

SUBCOMMITTEE ON SPACE SCIENCE & APPLICATIONS
COMMITTEE ON SCIENCE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

Statement by:

LAUREL L. WILKENING, VICE CHAIRMAN
National Commission on Space
University of Arizona

Mr. Chairman and members of the Subcommittee, thank you for the opportunity to participate in the discussion of the future of the civilian space program which you are undertaking today. In our review of the civilian space program, the National Commission on Space (NCOS) identified three major areas in which the U.S. civilian space program could expect to provide world leadership and thereby obtain substantial return for investment in them. The three areas are: first, science; second, exploring, prospecting, and settling the solar system; and, third, space enterprise. I wish to direct my remarks today to the first two topics; and, in particular, I will focus on the solar system - both the science as well as exploration and prospecting therein.

We are poised on the boundary of the space frontier. Our scouts, mostly robots, have traveled far and wide in this new territory - the solar system. Regular human expeditions are now visiting the first outposts in Earth orbit. The exploration of the inner solar system, that is, our planetary neighbors Venus, Mars, and the Moon, has gone far beyond mere reconnaissance. Indeed, human beings, including a geologist, visited the Moon and conducted scientific studies there, some of which were real prospecting. In the case of Mars, very sophisticated sets of robotic spacecraft, the Mariners and Vikings, have probed its atmosphere and surface and provided detailed photography of interesting areas of its surface. In the case of Venus, the Soviet Union as well as the United States, in separate missions, have provided substantial information about its atmosphere and surface. The work of the frontier pathfinders has been completed and the inner solar system is now ready for the prospectors and entrepreneurs in the inner solar system. The question now is from what country will they come?

In contrast to the first decade and a half of the space age, when the U.S. was the acknowledged leader in space science and planetary exploration, the situation in the mid-1980's is quite different. There is no longer a lack of activity by other nations. If the U.S. is going to lead, it cannot set its own leisurely pace. The importance of space is recognized world wide, and the pace of space activity on a world scale has accelerated greatly in the past five years. This past year has seen the encounter of Comet Halley by spacecraft from the countries represented in the European Space Agency, the Soviet Union, and Japan. The European Space Agency has announced as a long-range plan for its planetary exploration a program to return samples from primitive objects, either comets or asteroids. The Soviet Union has announced a series of increasingly ambitious missions focused on Mars, including a lander which will hop around on one of the moons of Mars making chemical assays there. They are also planning a mission to involve study of several asteroids, including the large bright asteroid Vesta.

On the other hand, the most recent planetary mission launch by the United States was Pioneer Venus in 1978. And while NASA has a plan for a series of missions to continue planetary exploration, this plan has stalled and, even worse, those missions that had been approved, face an uncertain future because of the lack of availability of a suitable launch vehicle. The Galileo Mission to Jupiter, the first major planetary mission mounted by the United States since 1978 and scheduled for launch in May of this year, is grounded indefinitely in the wake of the loss of the space shuttle Challenger.

Far from taking the steps that are necessary to bring about a major enhancement of the scientific activities undertaken by this nation in space in the early 1990's, our country seems to be doing the opposite. No new science missions are being considered by NASA at this time; no plan for developing deep space launch

capabilities is emerging, and tremendous uncertainty surrounds the funding of a replacement of the Challenger space shuttle. Rather than planning for the continued leadership in space science by the U.S., a lack of commitment by this nation to the civilian space program is resulting in a rapid erosion of our space science programs - from life sciences to astrophysics. The NCOS believes that space science is too important to the United States to be abandoned. But, by default, the U.S. is abandoning it.

Scientific research lends itself to international cooperation, and we strongly endorse the continuation of international scientific cooperation in space. However, we note a rapidly developing shift toward Soviet leadership in planetary exploration. As a result of a continuing, sustained effort, the Soviets have gained considerable confidence in their space program. They are now very open about their program, including televising launches and allowing real-time access to international science missions by Western scientists and journalists. Their Vega mission to Comet Halley was an example of the new attitude of the U.S.S.R.'s space program. The Vega mission involved experiments from France and Germany and participation by a few United States scientists. Many Americans saw U.S. scientists on television in the Soviet Union participating in the analysis of data at the Soviet mission headquarters. But did Americans stop to think about what they were seeing? Although this was a seemingly familiar scene to American television audiences, usually featuring scientists at Jet Propulsion Laboratory or NASA/Houston analyzing their data, what Americans were seeing this spring was actually coming directly from the Soviet Union. What is happening is that the U.S.S.R. is replacing the U.S. as the leader in international scientific cooperation in planetary exploration. And this is simply because their program is moving, and ours is not. We are not offering an alternative.

What should the U.S. be doing? The National Academy of Sciences and various scientific advisory committees to NASA have carefully and thoughtfully designed plans for space sciences in the future. The NCOS was not in a position to redo those plans. We evaluated them, and we found them to be appropriate directions for the future.

Less detailed planning has occurred in those areas of the space program that relate to prospecting, resource development, and industrialization in space. The NCOS, although not equipped to do detailed studies, did consider these areas. We know from our scientific studies that Venus is a very inhospitable planet. The surface temperature is high enough to melt lead. The surface pressure is a crushing 90 times that of the atmosphere on our own planet. On the other hand, the Moon and Mars, while providing their own particularly difficult environments, nevertheless hold out the prospect that extended scientific exploration and eventual commercial activity could take place on both of these objects. For this reason, our plans are directed toward these two objects.

We found that in the near-term there is a certain amount of overlap between the activities that are aimed at industrialization in space and purely scientific exploration. For example, for both scientific reasons and for prospecting, we recommend

- a robotic lunar polar prospector to examine the entire surface of the Moon from low orbit.
- probe missions to do subsurface analyses of the lunar surface and additional sampling missions from regions of particular interest.
- Earth and space-based searches for readily accessible asteroids, telescopic characterization of such asteroids, and prospector missions to promising asteroids.

A similar series of robotic prospecting missions on Mars and its moons could also be delineated. These studies would culminate in the return of samples from locales showing promise for future human activity on Mars.

We assume exploration and prospecting will lead to space-based industry. As economic activity develops in the inner solar system, humans will inevitably follow, just as settling of our western frontier followed the economic activity associated with mining and farming on the Pacific coast.

This country needs a national commitment to a civilian space program. This commitment must focus on specific goals. On the assumptions previously stated, we recommended a 50-year goal of establishing bases on the Moon and Mars. Such a long-term goal would allow the development of an orderly plan that will result in a lasting program rather than a one-shot space spectacular. It is the difference between Scott's and Amundsen's dashes to the South Pole and the building of the Alaskan Pipeline. The time has come for humans to move into space with the expectation of living and working there.

Mr. NELSON. Thank you, Dr. Wilkening.

Dr. Paine.

Dr. PAINE. Mr. Chairman, I'd like to ask Dr. Field for just a—one comment on the science program and then we'd like to make ourselves available for your questions and the committee's.

Dr. FIELD. Mr. Nelson, it's a pleasure to be here this morning.

I want to underline the very specific fact that our Commission is making a very specific recommendation at a time in which this Nation is in crisis with respect to our space program.

I accept and support this recommendation. I believe that it is—our Nation is best served if the Congress can bring itself to debate this recommendation and to either accept or to substitute something better. We need a vision. We need a goal.

Now, my other comment relates to the scientific portion of the report. In the lack of the presence of Dr. Thomas Donahue, who is chairman of the Space Science Board and who, I think, intended to be here this morning, it might be helpful just to point out that there has been a very thorough going study by the Space Science Board. That study has been under way for about 2 years. Its report is now in the process of being written and will be published, I hope, within the next 6 months or so.

I participated in the formulation of that report. In my opinion, the findings of the Commission in the scientific area are fully consistent with the National Academy study. I believe that when the Academy does finally speak on this issue that you will find full support for the scientific recommendations in the Commission report.

Thank you.

[The prepared statements of Dr. Field and Dr. Kerrebrock follow:]

CHAIRMAN
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VICE CHAIRMAN
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COMMITTEE ON SCIENCE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

Statement by:

GEORGE FIELD
Member, National Commission on Space
Harvard-Smithsonian Center for Astrophysics

National Space Goals

Testimony by
George Field
Harvard-Smithsonian Center for Astrophysics

I am honored to testify as a member of the National Commission on Space. I urge the Congress to begin a critical reexamination of our goals in space, and to give serious consideration to the goals recommended by the Commission.

As an astronomer, I am delighted that the Commission assigned high priority to the advancement of science. The achievements of our space science program have laid the basis for an exciting program in the future. The program described in the Commission Report, which benefited greatly from preliminary findings of a study now being completed by the Space Science Board, is aimed at understanding the evolutionary processes in the Universe that define its present characteristics, and at applying the new understanding to forecasting future phenomena, particularly those which impact human life.

This program will address questions at the frontiers of science, including the basic laws of physics, the evolution of matter in the Universe, the origin and evolution of the Solar System, the behavior of plasmas in the Sun and the space around it, the origin and evolution of life, and research on materials and living organisms in microgravity. A "mission to planet Earth" will monitor changes in the Earth, its oceans and its atmosphere, and by achieving a deeper understanding of the Earth, it will enable prediction of changes that will affect human activities. The space science program recommended by the Commission will integrate the findings of diverse scientific disciplines into a more unified understanding of the Universe and our place in it.

The Space Act of 1958 authorizes NASA to carry out activities in a number of different areas. In the light of subsequent experience, more specific goals should now be set by Congress. I strongly believe that America should pioneer the space frontier. A single challenging long-range goal should be adopted in order to mobilize our resources and our creativity. The Commission's Mission Statement on page 2 of the Report meets this requirement.

Human settlement of bodies beyond the Earth is such a demanding goal that it will succeed only if it is in harmony with the basic values and aspirations of the American people. Is it? The Commission deals with this question in the section entitled "Rationale for Exploring and Settling the Solar System" on page 3, and concludes that the answer is affirmative. I recommend that in framing legislation which will set new goals in space Congress should consider this question seriously.

The Commission recognizes that both manned and unmanned missions are necessary to achieve a cost-effective program. I believe that as detailed plans are developed, the objective of advancing science most cost-effectively can serve an important role in helping to decide when and how to use people in space. Some scientific activities, such as reconnaissance and mapping of planets and other bodies,

can be achieved at lower cost without using people in space. Others, such as the maintenance of complex facilities in Earth orbit, require people. As our scientific frontiers expand, people will be required to staff bases on the Moon and Mars. Once our scientific objectives are established, the proper mix of manned and unmanned missions can be chosen so as to minimize cost.

America should pioneer the space frontier peacefully and in hopes of increased world cooperation as recommended in the Report. In so doing, we will direct our energies not toward building new weapons, but toward building a new civilization. This task, requiring the courage, ingenuity and perseverance demonstrated by our pioneer ancestors, is one worthy of America.

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Statement by:

JACK L. KERREBROCK
Member, National Commission on Space
Massachusetts Institute of Technology,
School of Engineering

Jack L. Kerrebrock

Subject: **Space Research and Technology**

Mr. Chairman, Ladies and Gentlemen, my subject today is the Nation's need for an expanded, more stable, and more aggressive program of research and technology development in those areas which are critical to our continued leadership in space. The United States must substantially increase its investment in space technology if it is to retain leadership in the scientific and commercial uses of space, in the face of strong challenges from abroad. In financial terms, the current level of effort in Space Research and Technology supported by NASA is less than one-third that of the period from 1965 to 1970, when the U.S. was making such great strides in space. With the exception of those special areas augmented by the Strategic Defense Initiative, this shortfall has not been made up by other sources of support. In personal terms, we must renew the Nation's commitment to advancement of the intellectual frontiers of space if we are to expect adequate numbers of the Nation's brightest and most creative young people to make their careers in space, as many did in the earlier era.

The research and technology efforts which must be supported fall in two classes, those characterized as components of the Research and Technology Base, and those which are classified as technology validation or technology demonstration. The Commission recommends a factor of three increase in the NASA Space Research and Technology Program which supports a significant part of our space technology work, including most of that done in universities. It also recommends intensified technology validation efforts in seven technologies judged critical to our future in space. I wish to spend a few moments clarifying the role, and what I consider to be the seminal importance of the R&T Base. I will then discuss the seven key validation efforts, with emphasis on those for which congressional direction is especially important at this time.

THE RESEARCH AND TECHNOLOGY BASE

Technological advance is critical to all elements of our space program, scientific, exploration, and commercial. For example, although many valuable and exciting scientific investigations can be carried out in space with today's technology, major advances in optical resolution and telescope pointing accuracy are required to allow us to detect Earth-like planets circling nearby stars. Better propulsion, structural, guidance and control technologies are needed if our launch and orbital transfer systems are to be more reliable and economical. The technologies which are needed are many and varied. Some are rather specifically motivated by space needs, while many are of broad applicability. It is no exaggeration to say that applications in space are more technologically demanding than most terrestrial applications, in particular with respect to demands for reliability, low weight, and long life. Space needs force technology developments which can later provide large benefits in terrestrial applications, though the latter might not by themselves have provided sufficient motivation for the research and development.

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These technological advances cannot be programmed. The character of research is such that, particularly in its early stages, its application cannot be reliably predicted. Research must therefore be pursued on a broad front, to identify and quantify technical possibilities, before their usefulness can be judged. Such a research and technology program is therefore properly conceived as OPPORTUNITY GENERATING, rather than directed at known, specific applications. When the technological opportunities have been identified and the risks understood, it is then important to move aggressively to a level of thorough quantitative understanding to provide a basis for deciding whether and how to employ the new technology. It is this latter phase which will be addressed in the following discussion of technology validation.

How much support for the R&T Base is enough? This is a question on which recent administrations have had difficulty adopting a long-range view in the face of overall budget stringency and the lack of clearly definable products which may be expected of research in the near-term. Though few dispute the long-term benefits, the question often asked is: "why now, what's the hurry, can't we stretch it out?" There are at least two arguments which counter this view. One is that delay will cost us dearly in missed opportunities, in ideas and technologies which are evolved and pursued outside the U.S. But still, what level of support is required to ensure that we are not missing opportunities? I believe the answer is that we should provide sufficient support to make the best possible use of the precious resources of research talent presently in our universities and research laboratories, and to ensure that those bright young people who are interested in space will not be deterred from research careers by lack of financial support. In the end the answer still rests on informed judgment; it is the judgment of the National Commission on Space that the part of our Space Research and Technology Program supported by NASA should be increased by a FACTOR OF THREE.

TECHNOLOGY VALIDATION PROGRAMS OF HIGH PRIORITY

Technological research is essential and should have very high priority, but it is not sufficient to ensure the availability of the best possible technologies to our space programs. Before new concepts derived from research can be employed in expensive, tightly scheduled flight programs, they must be carried through the steps of engineering design, test and evaluation to the level of maturity at which reliable estimates of weight, manufacturability and cost can be made, before they can be incorporated in large, costly systems. It is essential that these steps be taken before systems commitments are made, because unexpected faults or difficulties which cause schedule slippage in large programs are extremely expensive, and to no good result.

The Commission recommends for special priority the following seven technology validation programs.

1) Flight research on aerospace plane propulsion and aerodynamics;
2) Advanced rocket vehicles;
3) Aerobraking for orbital transfer;
4) Long-duration closed-ecosystems;
5) Electric launch and propulsion systems;
6) Nuclear-electric space power; and
7) Space tethers and artificial gravity.

I offer a few comments on each of these, but will dwell at somewhat greater length on the first two, which have gained a great sense of urgency since the loss of the space shuttle Challenger and the subsequent failures in other launch systems. It became very clear again to the public in the wake of these very visible incidents that Earth-to-orbit transportation, far from having become a routine endeavor, still presents technological and management challenges of the first order. While it is not a complete solution to the crisis we find ourselves in, better technology offers the possibility of design and development in the future of Earth-orbit transportation systems which can meet the difficult requirements with larger margins of safety, hence greater reliability, and eventually lower cost.

Future Earth-orbit transportation systems will consist of unpiloted cargo transport vehicles and passenger transport vehicles using improved and advanced technologies. Our review of the space transportation area led us to the conclusion that the technologies critical to achieving better unpiloted launchers center in the manufacturing of the principal components of the vehicle: materials, structures, engines, tanks, guidance, and control. A second critical need is to increase safety and reliability while reducing the size of the checkout and launch crews now needed to support launches. This can be done through modern, automated readiness tests combined with hardware and software which is more tolerant of minor faults.

For passenger transport to low-Earth orbit, we need reusable vehicles that are robust and reliable. Because of the large energy change required to achieve orbit, the propulsion system dominates the character of the vehicle. Amongst the options are one- and two-stage rockets with hydrogen/oxygen or hydrocarbon/oxygen engines, two-stage vehicles using airbreathing engines in the first stage and rockets in the second. The most challenging possibility under consideration is a single-stage combined cycle system using hydrogen for airbreathing propulsion to orbit, capable of horizontal launch and hypersonic suborbital flight in the atmosphere. This is the concept envisioned as an outcome of the National Aerospace Plane Program (NASP).

The propulsion technology base must be vigorously extended for both rocket and airbreathing engines. Advances in durability of the thermal protection system and in light-weight materials and structures will pay off handsomely in lower operational costs, as well as improvements in the information, guidance and control systems. These vehicles can benefit from the major advances in computer technology that have taken place since the shuttle was designed if programs are initiated now to develop space-rated, fault-tolerant computers. All of these areas will require early technology demonstrations if the improvements are to be validated in time for vehicles to be operational by the late 1990's.

For the airbreathing option, extensive research and technology development is needed, whether it is used in an airbreathing first-stage, or in a single-stage vehicle. Here the critical technologies are in the Supersonic Combustion Ramjet Engine (SCRAMJET), a propulsion device that has been well understood conceptually since the early 1960's but has been experimentally validated only in ground experiments, and only up to Mach numbers of about 8. If the SCRAMJET is to meet the expectations it has generated for orbital launch its Mach number range must extend to at least 12, and preferably to beyond 15.

The essential feature of the SCRAMJET is that the air is not slowed to low velocities before the fuel is added, as it is in all other airbreathing engines; rather the hydrogen fuel is injected into air flowing at Mach 3 to 8 through the combustion chamber and into the exhaust nozzle. This minimizes the problems of high temperature and pressure in the combustor chamber which a conventional ramjet would encounter at very high flight Mach

numbers. However, it leaves one very fundamental and difficult problem to be overcome. This is that the amount of energy added to the airflow by combustion of the hydrogen is small compared to the kinetic energy of the airflow into the engine, or by the same token small compared to the kinetic energy of the flow out of the nozzle. Thus the thrust, which results from the conversion of the fuel's combustion heat into kinetic energy of the nozzle flow, results from a small difference between the nozzle flow velocity and the flight velocity. This difference is only a few percent at Mach numbers above 15.

It follows that success for the SCRAMJET depends on extraordinary sophistication in fluid mechanical design, development and operational control. There is reason to believe that with modern supercomputer technology and experimental capabilities, a design can be achieved which will yield specific impulse values, averaged over the Mach number range from 0 to 23, as high as 1,000 to 1,500, which is two to three times that of a hydrogen/oxygen rocket. If these values can be achieved, the fraction of the vehicle mass which must be propellant may be small enough that single-stage operation to orbit becomes practical.

The critical issue here is the validation of the propulsion system at high Mach numbers. Since no ground test capability is available at such Mach numbers, and indeed none seems feasible, the propulsion system must be validated experimentally in flight. This is the principal purpose of the National Aerospace Plane Program, which the Commission strongly endorses.

Aerobraking is a critical technology for orbital transfer; by reducing the propellant consumption required to return from a high orbit to a low-Earth orbit, it will reduce by as much as half the mass of the vehicle which is required to carry a given payload to a high orbit. Here the critical technologies are light-weight, heat resistant structures for the drag brake, and precise guidance and control for the trajectory, which must just "skim" the atmosphere. The basic technologies are in hand; what is needed now is a technology validation experiment.

Electric propulsion offers great benefits in reduced system mass for scientific missions requiring large velocity changes. Indeed, for some missions to the outer planets it is enabling. There are two elements to an electric propulsion system: the propellant accelerator and the electric power source. One class of propellant accelerator, the "ion engine," has been thoroughly ground tested and also operated successfully in orbit in small sizes. In these tests photovoltaic cells provided the power. While this is satisfactory for small thrust levels in the inner Solar System, the only practical power source for challenging missions to the outer planets is nuclear electric. We need a moderately sized solar-electric propulsion validation experiment to raise confidence in electric propulsion to the level that it can be considered for difficult missions, for which it is the only feasible alternative.

Nuclear-electric power offers much for space activities, in combination with electric propulsion as just noted, as a compact, lower mass alternative to large solar arrays for space stations, and as sources of power for bases on the Moon or Mars. There is a program, cooperative between the DOD, DOE, and NASA, to build and ground test the components of a high performance nuclear-thermoelectric system capable of powers in the order of 100 kilowatts. This SP-100 program at present derives nearly all of its support from military sources. I urge you to be aware of its importance to our civilian space program as well.

The last technology for which a technology validation is especially recommended, the "tether," is a long tensile connection between two orbiting bodies. Because of the economies which it offers in transferring energy between the bodies, and its potential for providing

variable gravity, it is likely to play an important role in future space activities. It has been studied extensively, theoretically, but an in-space validation of these studies is needed soon so that the manifold advantages of tethers can be exploited.

In closing, let me note that the space research and technology development I have briefly discussed provides the seeds for our future in space. It provides both the knowledge and the people essential to our future. I hope you treat it favorably in allocating our national resources, for in this area I believe the return will be excellent.

Mr. NELSON. Thank you, Dr. Field.

Dr. Paine, would you like Kerrebrock, Dr. Sullivan——

Dr. PAINE. No, I think probably that in—we would respond to your questions and they will both have opportunities to comment.

Mr. NELSON. OK. Mr. Chairman Fuqua.

Mr. FUQUA. Well, thank you, Mr. Chairman.

First of all, Dr. Paine and the members of your Commission, I would like to, as I have privately and publicly, but again publicly, commend you for a very excellent report. I think it is balanced. It recognizes—it sets—I don't even think it's an overly ambitious program. When we are talking about what's happened in the last 25 years, that these are not altogether technological breakthroughs that we are having to seek to achieve the objectives that you have outlined. I think it's very balanced. And I think the point about the science programs certainly deserves careful consideration, because, as has been pointed out, we have not intentionally, but through neglect, I guess, or budgetary restraints and other things, that we have somehow neglected the science programs in the fashion that I would like to have seen them go.

We had several significant things that were to happen this year with the Hubble telescope and the Galileo Mission and some of the others that have been indefinitely postponed because of launch capability. Hopefully, that will be resolved in the near future and we can move on with those programs. But as you know, it takes several years in order to develop a program. It seems that we've been going in 10-year cycles in some fashion. I don't know why, but that seems to be the way. And—but I hope that—that we can get the scientific community—and I think you have developed a very, as I said, a very sound program. But we need—and that was the reason that the committee chose a Commission of this type rather than have OMB make these decisions.

I hope that we can get some bold leadership from the administration and from the Congress in moving forward with the implementation of this—of this program. It has been now 10 years since the Viking landed on Mars. We have no program to accomplish a similar type feat of a landing on Mars. We have a fly-by but not a landing on Mars. But I think we need to—we need to pursue this.

One of the things you did not—I don't specifically gather—would be the international cooperation in some of these programs, particularly—I've been talking recently about international in big science and things that are expensive. The question came awhile ago: What language will they be speaking when we get there? And I'm not so concerned about the language they speak—the fact that we are playing a major role in getting there.

Do you think this is—lends itself to international cooperation, particularly the Mars and the Moon exploration?

Dr. PAINE. Mr. Chairman, there's no question that this program would give the United States magnificent opportunities for cooperation with many of our friends, and I think also the opportunity for beginning to build a better bridge of scientific understanding with the Soviet Union is also a major possibility here if we will seize these opportunities with initiative.

In our report we discussed the international aspects and we were fortunate to have Jeane Kirkpatrick, who had extensive experi-

ence, of course, in the United Nations, as our U.S. representative there. And we convened meetings with other international experts. The State Department has major inputs. And just as we have, I think, many inputs from the scientific community and many technological inputs from the aerospace engineering community, we also had a number of inputs from our friends in the European Space Agency.

And as Chairman Nelson mentioned, our trip to Moscow gave us some opportunities there. So there's no question at all that international participation and contribution will be extremely important. But I'd like to make one basic point. And that is, unless the United States adopts some kind of a plan that has a prospect of continuing activity aimed at certain goals, it will be very difficult to get other nations to work with us if they don't know where we're going, they certainly don't know the degree of interest they have in cooperating, nor do they have any confidence that there will be programs there for them to cooperate with.

And so I echo Dr. Field's comment that I think is very important, that we use this hiatus in space flight that is forced on us by the *Challenger* accident to review the future direction and thrust of the American space program and we hope very much that we will emerge from this with a long-range plan similar, at least, to the one that we have proposed.

Mr. FUQUA. How would you propose that we begin the implementation of this? I know we can't bite off the entire project in fiscal 1987. But how would you propose that the Congress—what would be the course of action that you would recommend for this subcommittee and this committee to begin?

We have trouble initiating new, bold projects like this without the support from 1600 Pennsylvania Avenue, and particularly with the commitment that this would make. But what would be your proposal for action implementation?

Dr. PAINE. Well, there are three basic things that we think are urgent. Most of the material in our report is important but not urgent. There are three things that I believe are urgent. And the first of these is we recommend that you direct the Administrator of NASA to review our report and by the end of the year to give you his comments as to what it would take for NASA to move in this long-range direction as the future space agenda for our civilian space program.

We would like to see you direct him to do that by the end of the year, giving both you and the President his proposals for how our report would be implemented.

Mr. FUQUA. Let me propound another question. You have walked in those shoes before. You know the problems that are facing NASA right now in just getting the program back on track, not only with the shuttle, but also with the space station and many other budgetary problems that are facing NASA.

I'm not sure that Dr. Fletcher wants another chore of this type thrust on him in the last 5 months of the year.

Dr. PAINE. On the contrary, I think that as he grapples with all those alligators that a request from this committee that you have him look at the plan for draining the swamp would be very welcome. [Laughter.]

The people who are going to be working on fixing the space shuttle and the management program are different people. Now the people that would be responding to this request would be his long-range planning people, and I think they need the encouragement. And I think that Dr. Fletcher would be just delighted to have you instruct him to do this.

The other two points I wanted to make were that we also have had the feeling that the long-range space policy of this country and the staff work required to get there perhaps has broken down. And I think that asking a Commission of this sort to be formed to do this represents somewhat of a vacuum.

We, of course, have a sunset clause and we will be giving up our offices at the end of the month and going out of business. But we would propose that you reexamine the question of a National Space Council. It's in the enabling NASA legislation. I believe that for many years it performed a very useful function. And one of our recommendations is that you review the possibility of reestablishing this.

You may recall that President Nixon discontinued the Science Adviser office and the National Space Council. The Congress has subsequently suggested to the President that the Science Adviser be reinstituted, which has been done. And we raise the question now as to whether or not we wouldn't be getting better staff work in space policy if the National Space Council were revived.

Mr. FUQUA. I think that's a very excellent suggestion. And that is part of the recommendation of the Subcommittee on Space Science and Applications in the NASA authorization bill for this year. So——

Dr. PAINE. Yes.

Mr. FUQUA [continuing]. We are moving forward in that direction.

Dr. PAINE. The third very high priority urgent matter that I think comes out of our Commission report is that if indeed a long-range space agenda—a long-range plan for our civilian space program along the lines that we've proposed is adopted, it provides a wonderful blueprint not only for the international cooperation that you asked about, Mr. Chairman, but it also gives us a blueprint for the kind of technology base that we need to develop to bring these things forward so that we can do them more economically, with more assurance of having the technology available when we have to make basic decisions—on the next generation post shuttle launch systems—that we will have the technology in place that will allow us to make wise decisions.

We believe that the space technology development area has been starved for funds in the last 10 years. Because of the pressure of shuttle funding, I think we are essentially living off seed corn that goes all the way back to the Apollo era.

So we would recommend also that your committee give very great attention to starting now the relatively low cost technology developments—investments that can save us a great deal of money in the future. Investments that can support, perhaps, a better launch vehicle complex than the one that we have today, that can allow us to maintain low cost access to space, and indeed, to reduce the cost of access to space in a way that really will save us money

in the long run even though technology expenditures would be made today.

Mr. FUQUA. One final question. Of course, funding is going to be a big item, particularly in the next several years as we are trying to proceed with efforts of budget deficit reduction. But the—what would be the cost offset between a man-tended lunar exploration versus a man-operated? And did you look at those costs trade-offs?

Dr. PAINE. We——

Mr. FUQUA. And I'm sure that question is going to come up.

Dr. PAINE. Yes. I'd like to ask Dr. Sullivan to speak to that. But let me just say that I think that we envision this as being very much an evolutionary system in which the very first return to the Moon would be done by purely robotic systems and teleoperated systems in which, because of the short communication time, it would be operated from Earth with effectors and eyes on the Moon. That would then be followed by the mixed strategy of both men and machines which would then become the norm.

And the question really relates to what is the best balance between the presence of people and the use of machines. And Dr. Sullivan, the first American woman to walk in space, has had hands-on experience as Chairman Nelson has had, in orbit, and I'd like to ask her to perhaps respond to your question.

Mr. FUQUA. Thank you.

Dr. SULLIVAN. Mr. Chairman, we did not request nor review specific cost offset figures from NASA. That, of course, would rely on having a very detailed design and a fairly concise implementation plan including the time frames, the time milestones, in which you would propose progressing from each of these evolutionary stages that Dr. Paine has outlined.

Our consideration of lunar outpost facilities did not need to go to that level of detail.

I would venture the speculation that you would certainly see some cost offset of a magnitude proportional to the sort of magnitude that you've heard in the figures for the man-tended space station approach in low Earth orbit.

Our film and many of our discussions in the body of our report do tend, by and large, to address the evolved versions of the facilities that we envision. That is, of course, not a facile approach that we have adopted. We fully recognize that each of these programs and each of these capabilities would have to begin with some seed facility that would have to evolve in a logical and progressive fashion.

And in a sense, what we presented for you here is, therefore, a road map of ultimate destinations. And, of course, it is a function of the national priorities and your abilities and wisdom in directing the Nation in each given year and authorization cycle to adjust the throttle, as it were, as we go along that road map.

We might be able to attain some of these objectives in fairly short order and others might indeed be delayed.

Our point really is to recognize that there is a very logical map dictated by the logistics and the geography of the inner solar system and by a variety of what we view as important technological, educational, and political milestones and objectives for the country. And that we should adopt that road map and agree and

understand that we are on that journey even though we may at times have to slow down.

Mr. FUQUA. It would seem that with the advances that will be made in robotics, which are improving rather rapidly, that within the next 10 years that we would have made significant progress in robotics and teleoperated equipment that this would lend itself for a rethinking of the total amount of man's commitment in operating particularly in the early stages.

I still realize there are certain things that man can do that machines can't do. But it seems like something that we must be very careful about as we proceed.

Dr. PAINE. We envision in fact the same question arising in American industry in the 21st century. It has already happened, of course, in scientific agriculture where we now operate the Nation's food and fiber industries with a fraction of the manpower that was formerly required—a very small part of our work force. We believe that the routine factory operator in the next century will follow the agricultural worker down into a much smaller group.

And we believe the major implication for this in space is that the same type of highly automated factories that will then be processing industrial materials here on Earth will facilitate that same kind of penetration on nearby objects as we mentioned in the TV tape.

Incidentally, I might just mention in connection with that tape, that we are making this widely available to schools. We have sent one to each one of the teachers who participated in the Teacher in Space Program. And we believe that this is a very good way of getting through to the young people of this country some of the excitement that lies ahead in the space frontier.

Mr. FUQUA. Let me commend you for that, and also again commend the Commission for their time and dedication and outstanding product that they produced.

Thank you, Mr. Chairman.

Mr. NELSON. Yes, sir, Mr. Fuqua.

Mrs. Meyers.

Mrs. MEYERS. You have said—well, I think all of you have indicated that you think that what we need to have is vision and goal and commitment to the future. I guess I'd like to ask—you've said that maybe the first thing that we can do is to direct the Administrator of NASA to review and report by the end of the year on your report, and that we should reactivate the National Space Council.

Give us some other directions as to what should be the first things that we should do as a committee. Are they budget decisions? Are they policy decisions? That we need to kind of be the leaders in that vision and goal and commitment that you talk about.

Dr. PAINE. I think that the point that we are stressing here this morning is that the Nation's space program has probably never been more in need of the kind of policy look, the kind of recommitment and dedication, that in the wake of the *Challenger* tragedy we would take the position that it's the perfect time to reexamine where we're going in space.

We in our report, of course, have stressed the exploration of the Moon, and Mars, with robotic percursors, followed then by increasing human presence. And we believe that this is in deed a sound long-range goal within which you can then structure your look. And the administration, of course, we are proposing the same thing.

We believe that this type of a space agenda for the next century will restore NASA's vigor and in sense purpose. We believe that also it would attract top people, top talent, really some of the best minds of the 21st century that we believe would be delighted to work on such a bold program.

We think also it would attract the type of international support, participation and contribution that would be absolutely essential for continuing American leadership.

As far as the budget goes, I think that in the long-range sense that one of the lessons, perhaps, as we look at the last 10 years, that we might gain is that perhaps we've tried to do too much on too small a budget. Perhaps when we decided that we could get by to the end of the century without an accident with four shuttle orbiters, perhaps having gone for five, with the benefit of hindsight, would have been a cheaper, more cost-effective way to go.

I think that the question of how much it's going to cost us now with this long delay, very likely would have paid for perhaps a somewhat greater investment.

I think, too, that Mr. Donald Regan at the White House has been quoted as asking the question: Why should we go for a fourth orbiter? Why don't we go to a next-generation launch vehicle? I think it's a very good question for him to ask.

I think the answer tends to be that we haven't really done the technological homework. And so I think, Mrs. Meyers, that one of the things that we would like very much to have you look at is this—is this broad balance throughout the space program. Are we really doing the things that are required to make it a sound well managed program.

Have we got the spare parts in the budget? Do we have the technology in the budget that we're going to need to make those future decisions?

Do we have a good balance between the planetary exploration program and the launch vehicle program? And are they phased in such a way that we're not forced to come before this committee asking for very high funds one year and then low funds another? Are we managing it that way?

I don't know whether space policy is what you'd call this. Perhaps sound, long-term management of the space program is the thing that space policy would get to.

And, again, it's very much the hope of this Commission that our report will help you in your look at this longer range future. The very fact that we have a number of questions of do we replace the orbiter or not, which still haven't been addressed, although it's been many months since it became clear that we'd have to make those judgments, shows on the one hand I think the complexity of the judgments that have to be made, but also I think they show perhaps a requirement for a little bit more focused staff work and a little better plan and understanding of where we're going.

Mrs. MEYERS. This question might be heresy. You have really put the—an emphasis, and I think we always have indicated an interest in the commercialization of space. But it seems to me that the Soviets have not emphasized commercialization of space as much.

Is that a mistaken conclusion?

And it seems to me in emphasizing more just the scientific aspects of it, they have been able to move ahead more rapidly.

Should we change our focus?

Dr. PAINE. Well, the commercialization of space is something that we looked at and I'd like to ask Dr. Kerrebrock, perhaps, to comment on that.

I think that throughout our report you'll find on balance we've been pretty conservative. There are those who don't think so. But one of the things that we emphasized was that we were not going to go to anything that wasn't really in the laboratories today. We don't have any antimatter propulsion, fusion propulsion. There are a number of ideas that people are working on.

We tried to restrict ourselves to things that were in the laboratory today. And in the space commercialization area, therefore, we tried to restrict ourselves to things that we were pretty sure there would indeed be an opportunity for private investment and for a commercial return.

We believe that the largest next opportunity in space commercialization would be in the launch vehicle area but we are not optimistic about the present shuttle being operated on a private basis. We think this must be operated by NASA. And we are not very optimistic that the present expendable launch vehicle fleet, which is all based primarily on old military missiles, really has the opportunity for economic competitiveness.

But let me ask Dr. Kerrebrock, who has got some very firm ideas, I believe, on this subject.

Dr. KERREBROCK. That sounds like a setup. [Laughter.]

Let me comment first on your question about the Russian space program—their emphasis on commercialization. I think that within the Russian culture and within the Russian way of doing things, they have made a very large commitment to what they would call the commercialization, or the industrialization, of space.

Now, when—I must say that when you speak with Russians, they refer to industry, you know. And their industry is a set of Government-controlled and Government-operated organizations. But, nevertheless, they are the components of their society that produce objects for public consumption or for the military, and so forth—they call them industry.

And I was interested to note in the article in the New York Times this morning that they placed a very large emphasis on the industrialization or the—yeah, let me say the industrialization of space which is taking place in their space station, which, of course, has been up there and operating now for some years—and, I mean, they just came back from spending 4 months up there.

But one of the points that they made quite directly was that—that they were systematically, and deliberately developing, the capability for industrial activity in low Earth orbit, and presumably, they plan to extend beyond that.

I would also like to make the point that the United States pioneered the commercialization of space. The only existing commercially viable activity in space, at the present time, is the communications satellite industry. And we pioneered that, developed it. COMSAT is a U.S.-not-for-profit corporation. INTELSAT is an extension of that. And it is a going, viable thing.

Now, some people tend to think of commercialization of space as being exclusively the manufacture of products—some set of products—in orbit for use either there, or on the surface of the Earth. I submit that that's too narrow a concept of the commercialization of space. And that one might think, in fact, of the commercialization of space as analogous to commercial activities here on earth, where the commercialization really consists of some commercial profit-making organization, privately funded, therefore, accepting responsibility for activity in space. And it's conceivable that either the first, or the second space station, which is put in space by the United States, will in that sense be a commercial venture.

Now, as you know, there is a proposal under way to put a platform into orbit which would be operated by a private organization. And I think that is in the sense that I would consider it, commercialization.

Thank you.

Mrs. MEYERS. Thank you, Mr. Chairman.

Mr. NELSON. The Chair recognizes Mr. Brown.

Mr. BROWN. My own feeling is that you've prepared an excellent report, which will be of great value to the Congress, and to the people of the United States, and I want to commend you for it.

I think you all recognize that the future course of a space program requires leadership, and it requires public support. And you are trying to achieve both by encouraging us to take leadership and by providing a basis for public understanding of this.

I wanted to inquire what in your mind is going to be the institutional basis for continuing this program of public understanding of these space goals. Now, you've got a nice contract with Bantam Books and you've got a—you've been distributing this tape. But you are going to go out of business next month.

Is there going to be a framework under which we can continue to excite the public mind with these ideas over the next several years, for example? Because that's what's going to produce the leadership in Congress. We are great at leading when the public is pushing us to lead. [Laughter.]

Dr. PAINE. I think you've asked a very delicate question for us. In our final meeting of the Commission yesterday, the Commissioners pledged themselves to continue to work on their own, as private citizens over the next year, to do everything possible to keep public awareness of the questions and issues that we've raised in our report.

We have had discussions with the Aerospace Industries Association, which had a meeting recently, that—and they have pledged to do everything they can to help to get the type of program that we have proposed here implemented.

We have had similar assurances from the Planetary Society which, as you may know, is the largest of the groups—60—100,000

people belong to that. And not only in America, but in other countries.

The L-5 Society has chapters in every State of the Union. They have also indicated that they plan a vigorous campaign among their membership, and through them, out into the public to try to raise the consciousness of America, as to the values and importance to our future society of bold investments on the space frontier.

So, I believe that as a result of this report, that we have some kind of a potential rallying point for those in this country who are very concerned about our future in space, and we hope very much that it will attract continuing support. Someone mentioned to me yesterday that whenever a question about the future astronomy programs of the country comes up, people reach for the Field report. Dr. Field produced a very basic document.

We hope very much that not only in the next year or two, but perhaps for the next 10 years, or even beyond that, that this report that we have prepared will serve as some kind of a basic guidepost for future committees, like yourself, who are asking the question where we're going in space. And that the public discussion can focus around this.

Mr. BROWN. Would you consider it appropriate for the National Aeronautics and Space Council, which you are recommending, to play some sort of a role in maintaining this public discussion? That seems to me a little foreign to its previous mandate, and I am just wondering how you felt about that.

Dr. PAINE. I think—as Administrator of NASA, I was always very conscious of the fact that there is a very sharp line that you must not cross over, which involves the expenditure of public money to support a public program. So I think that the National Space Council, as I see it, would not have any role as NASA has, not in the promotion of space. But by the very act of laying before the American people through the Office of the White House, the future agenda, the future goals, the leadership that the President can provide, I think that this then engenders the national debate. The press comes in, the Congress comes in.

So in that sense, yes, I think that it would help the public understanding, but not in a direct way.

Mr. BROWN. I sense a certain deficiency which is probably carefully calculated in your report, and that was to avoid a discussion of the two space programs that we have, the military as well as the civilian. The military space program, as you know, which historically for a generation was about on a par with the civilian space program, is now at roughly twice the levels of the civilian space program. It is at the level that you are recommending for the civilian space program, and that the total space budget of this country is not $7½ billion or thereabouts, but closer to $24 or $25 billions.

The question of balance has to be considered. If we were to revert to the historical balance of roughly equal civilian and military space programs, all of your problems would be solved, from a budgetary standpoint.

Did you recognize this and feel it was beyond your mandate to talk about this kind of a balance?

Dr. PAINE. Yes, you very specifically asked us to confine ourselves to the future of the civilian space program, but at the same time, to be aware of what was going on in the military space program. So, we have had the briefings from the Air Force on the National Aerospace Plane. We had the briefing of the joint NASA-Air Force study that is now examining the future launch vehicle mix of the United States, but we have confined ourselves entirely, as requested, to the civilian space program.

Now, you also asked us to take the shuttle program as a given and the space station program as a given, and to confine our recommendations, then, to what follows the shuttle and the space station program; what lies beyond the low earth orbit operations which are already national programs.

So, to that extent, our report is somewhat deficient. But I think on balance it was probably a very wise move to give us this charter out here because nobody else really was looking at the future and, therefore, I hope that we have produced something useful.

But let me make one final comment. You and I have discussed this on various occasions. To me, the distinction between the military program and the civilian program is somewhat artificial, that we're both trying to do in many cases the same thing. You want to get reliable launches to low earth orbit. You want to do it at the lowest possible cost with the greatest safety. I think that when it comes to programs like the shuttle program, they really have to be designed in such a way to try to handle both sides of the Potomac.

For that reason, I think that we need to have a vigorous program in the military which looks at the military requirements, and which is—you'd make the decision on how large a program you have on what do you need in military communications. What do you need in military surveillance, reconnaissance? What do you need in the area of navigation, weather observation, and you decide your program levels on that basis.

Where you tend to get an overlap is in questions that we're in, for example, now in the SDI program—Strategic Defense Initiative—where there are requirements for the very accurate orientation and tracking of very large mirrors. Now, Dr. Field would love to have very high precision tracking of very large mirrors because if he could get to some of the objectives which are equally—just about the same objectives you have in SDI—it might be possible to look at a nearby star and actually detect whether or not there were planets in orbit around it.

If we could then get a spectral response from those planets, we might even be able to see whether or not there's water vapor on one of those planets as in our own earth. We might even be able to see whether or not there was oxygen in the atmosphere of that planet which might indicate a biological process going on.

So, you can say, well, there's a military program that in order for beam-directed weapons to have high accuracy, requires this very precise pointing. You can also say that the astronomy community would love to have the same.

I think the question that you gentlemen and ladies have to decide, and which we have to decide as a matter of national space policy is, what is the balance of objectives? Do we really give the American people the best return on their space dollar by having

parallel programs, overlapping programs? Should we just give the military that assignment, or should we just give NASA? These are very difficult space policy questions. I think that working with the White House, with the Pentagon, with NASA, you must then make the judgments as to what these programs will be.

Mr. BROWN. Well, I don't differ with that. I personally have supported a very vigorous military space program. But there comes a point when you have to consider what the total national security requires, and it seems to me that our space program and your report neglects the security implications of a strong civilian space program in terms of what it could do to protect the security and advance the development of all of the nations of the Earth.

You don't deal much with the so-called applications programs which could result in this kind of enhanced security.

Dr. PAINE. Well, I think perhaps we will plead guilty to that. Perhaps we took too seriously the stricture that we not get into the military programs and that we stick to the civilian. I would submit again that when it comes to the basic technology there is no such distinction, the technology can be used either way. So I do think you tend to come to a balance.

My own personal view—which perhaps is somewhat parochial—is that when you get to the point we are reaching today, where the military's space program gets to be so much larger than the civilian space program, that perhaps this committee should take a look and see whether or not the implications of having a somewhat bolder civilian space program might be such that it would be to the national advantage.

I think that there is always the possibility that a vigorous civilian space program, if there are arms control arrangements, or agreements, or other things which would restrict the military side, having a very vigorous national program certainly increases the total national security. It constitutes essentially an industrial reserve. We train the young people. We get used to operating in space in new, innovative ways. We develop new types of equipments and systems, which, if they are then later required because of a change in the international scene and the defense sector, are available to the country.

Mr. BROWN. Well, I am not going to fault you for these minor flaws in your otherwise perfect report. [Laughter.]

But what I am saying to you is, that the fundamental policy decisions which will determine whether you get the half a percent of GNP that you need instead of the quarter you are getting today will revolve around the total picture, not just what you are presenting.

Dr. PAINE. Yes, I think that's a very fair statement. And I think, too, when we talk about military systems there tends to be some kind of a feeling that perhaps they are aggressive systems, I would certainly submit that the ability to monitor arms control treaties from space has perhaps been one of the greatest contributions of the space program, making possible a degree of agreement between the United States and the Soviet Union, which would not be possible without this. I think the American people should be enormously grateful to that part of the military space program.

Mr. BROWN. I agree with that 100 percent, Dr. Paine. I won't belabor the point further, Mr. Chairman.

Mr. NELSON. Thank you, Mr. Brown.

Mr. Walker.

Mr. WALKER. Thank you, Mr. Chairman.

Let me also add my accolades to others who have gone before me for the work that was done. I think it's very important work. I think it does help sketch a very vigorous future for our space effort, and I congratulate the Commission on the work that you did. Let me also congratulate you on a side of the Commission's work that I had some degree of interest in, and that was that you did this work within budget. I want to congratulate you for doing that, and for coming forth with a report that I think we can be proud of, and doing so in a way that met a very stringent criteria of fiscal discipline. I think that that is something we ought to also be pleased with.

Let me follow up a little bit where Mr. Brown was going. But to come back to the issue that you've raised of putting one-half of 1 percent of GNP into this effort—that's where you see us going in order to implement this kind of a program. I think that that is a very interesting and good figure maybe to work with.

But do you see that as being a figure which is a Government expenditure figure, or is that a commitment of our society as a whole to a civilian space program? What does that figure precisely mean?

Dr. PAINE. That figure, obviously, had to be done somewhat arbitrarily. When I was operating the space program it was about three times the size that it is today in those terms. I think that after the Apollo Program and under the requirements that we pay for the Vietnam war, and the period of stagflation, and the growth of the military space program, and perhaps many other reasons, a decision was made to take it down to one-third.

I think with the benefit of hindsight, the wisdom of cutting that far back might very well be questioned today.

However, in our approach, and one of the things Chairman Nelson asked about was our methodology. We laid out where we thought mankind would be going in space over the next 20 to 50 years. From that we then structured a series of steps that we believed would be appropriate for the American space program to retain our leadership in space, then to try to get a feeling for the pace of advance, having laid out the direction of advance, we had to make a decision as to what level of expenditure would be logical. We were also looking, of course, at the expected increase in technological capability, and we commissioned a study to try to get some kind of a feeling for where the gross national product of America would be going.

We made the decision that perhaps one-half of the peak expenditures of Apollo would be about a level that, in our view, would indeed make America preeminent on the space frontier. Then we laid out the specific steps, year by year, as we opened up the Highway to Space, and then followed that with a Bridge between Worlds, kept a very vigorous science program, technology program, that this would be the series of steps.

We, however, did not put within this, Mr. Walker, the additions that we thought would come by private investment. So that our

recommended levels of expenditures are the government portion, not just NASA, but also NOAA, the atmospheric work, and so forth. But it does not include the private investment. Nor does it include the international participation. We believe that a vigorous American program of the type that we have proposed here would attract a fairly large participation on the part of the European space program, on the part of the Japanese, perhaps eventually the Chinese space program, and that, in addition, there would be cooperative opportunities with the Soviet Union, perhaps, that would further allow us to get more space program with less space budget.

So, the recommendation that you see here is basically that for the NASA and other civilian government space programs to be supplemented by fairly substantial foreign and commercial investments.

Mr. WALKER. OK, that makes it very clear. It concerns me a little bit, though. First of all, if we are going to start down the road suggesting that at the present time we ought to be giving $25 billion to NASA, which is essentially where we would be right now if you took the GNP, which is at least a threefold increase in our commitment to civilian space at the present time.

I think in outlining a policy framework to Congress right now that suggests that level of commitment, that it doesn't get done. The question that I have in my mind is, at what point in the future is Congress ever going to be willing to come up with that kind of money? Because it's a figure, obviously, if we have a growing GNP that continues to increase fairly significantly over a period of time, and if in fact we are tied to that kind of financial commitment in order to achieve this, that we may never be able to convince policymakers to make the commitment to this future, which concerns me.

Now, let me ask you this, then, doesn't it make some sense to try to expand that figure into the private realm, try to come up with a figure that would be an overall figure as to how much as a society we ought to be commiting to space, not only as a Government, but also as private industry, maybe also blending in the military—although I'd prefer to keep it in civilian here right now—and decide what commitment of resources, and then begin to look at how do we marshal those resources to do that. Because I think the marshaling of resources as a society in order to achieve some of these goals is a far different question than marshaling the tax dollars in order to achieve these goals.

Dr. PAINE. Let me——

Mr. WALKER. I don't see anything in the report that talks in those terms, and I'd just be interested in getting the reaction of the Commission to——

Dr. PAINE. Let me give you a brief reaction and let me ask Dr. Kerrebrock also to comment, because he again has strong feelings here.

We felt that the requirement at the present time was to lay out a long-range future agenda for the national space program, and we felt that it should be done in such a way that it would attract private investment, but that those decisions would be made by the private investor, based on the opportunity that was perceived for an investment to return a satisfactory return. Also a program that

would attract foreign participation and contribution on the basis that if the Americans are indeed going to open a bridge to the moon and begin to do scientific research there, begin to develop new types of processes, that certainly the Japanese would not like to be left out of this, the Europeans were not to be left out of this.

So, in structuring this as a national program, we certainly gave a lot of attention to making it sufficiently attractive that it would bring in those other two. But we recognized that those judgments would be made by other mechanisms. The Europeans, the Japanese, would make their own decisions, and the investing public would make theirs.

Now, perhaps Dr. Kerrebrock could speak more knowledgeably here.

Dr. KERREBROCK. No, I certainly wouldn't pretend that. But I would like to give you a slightly different viewpoint. I would like to suggest that sheer dollar outlay by itself is not the only measure of the vigor and health of our national space program. To me, perhaps the most important measure is how well the Nation's space program as husbanded by NASA with industrial participation and academia, and so forth, including all the participants—how well it makes use of that priceless pool of talent that we have in the United States of people, both young and old, who are dedicated to the kinds of scientific and technological things that characterize the space program.

Now, you know, the space program is in a real sense the technological spear point of the United States. It has always been viewed that way. To some extent, it still is that way in spite of the fact that the computer industry and its offspring have very high visibility now.

I submit the pool of people who have been born since 1958, you know, the first people who were born after Sputnik are about 30 years old now. They are in the universities, they are in the research laboratories, and so forth. Very many of them are intensely dedicated to space, to doing exciting, intellectually interesting things in connection with space, or in space. They are watching to see what the national commitment is to this. And if we don't take the step of adequately funding activities which are going to draw on and capitalize on that pool of talent, then I think the United States is making a very serious mistake.

Now, I would like to come back, if I may, for just one more moment to Dr. Paine's answer to Chairman Fuqua's question—the three things that the committee could do at this time. The third thing he mentioned was to make a commitment to technology. I submit that without any danger of making errors, or of wastefully spending the Nation's resources, the Congress could move ahead with an increased commitment to support of the research and technology, which is crucial to the future of the Nation's space program.

It is essential for science. It is essential for any large systems that we would mount in the future. This is an area which consumes a very small fraction of the total budget, but which is absolutely seminal in its importance.

Dr. PAINE. Well, I hope he responded.

Mr. WALKER. I'm not certain he did.

Dr. PAINE. You ask difficult questions.

Mr. WALKER. Yeah, I'm not certain he did. I agree with what you said, but I come back to the premise of my question; I think I got an answer again that suggested that the only way that we are going to achieve our goals in space is to do it with a Government program. And that the level of commitment that we have here is spending by the government. What I suggested is the premise to my question is: if we are going to rely on that, we are not going to get very far very fast.

My question is whether or not the Commission looked at the potential of marshaling, not just Government resources, but our resources as a society in order to achieve these goals.

Let me give you a couple of examples. Dr. Kerrebrock mentioned earlier that our first space station, at least maybe our second one, is likely to be a private space station. Now, that's a major resource that's being committed by the private sector, to something which fits very well into the space future as envisioned by the Commission.

I don't think that we can ignore that as a potential. When we look at aerospace plane. Aerospace plane is very important research, and development, on the part of the Government. But when it comes to actual access to space it may well be, that the purchase of that aerospace plane is not necessarily a Government purchase, as the shuttle program was, but will be convincing airlines, and a number of other people to make a billion dollar investment in that kind of an aircraft—that the real future may lay there. And that in fact, we will end up with major resources being committed to this space future, that are not necessarily Government resources.

And my question is: Shouldn't a part of the space policy development, that is taking place right now in a time of limited resources, be one of trying to figure out what policies are necessary, in order to encourage that other resource—those other resources into this space future?

Isn't that just as important as coming up with the specific Government dollars that we derive from tax sources?

Dr. PAINE. Well, I'm not sure that it is. And I think if you look at our report, you will find that we have given fairly heavy attention to the questions that you raise, but they are very difficult questions.

We are proposing here, for example, that in the event that the experiments on the space station do, indeed, come up with industrial processes, new vaccines, new semiconductors, space manufacturing of a preliminary nature, that private investment, in what we call an orbiting industrial park, be encouraged. And we even have some ideas in here, on how such investments might be encouraged from the private sector.

We also point out that in the event that it's determined that in geosynchronous orbit, where we begin to get larger, and larger antenna farms, that a teleoperator capability is appropriate, again we feel this is an excellent opportunity for private investment, since they will be private satellites—because of the past successes we've had in privatizing the communications satellite industry.

So we certainly agree with your basic thrust. But I think we come back to the basic point, that if the investing public is really

going to have the opportunities to invest on the space frontier, that there are certain prerequisites on the part of the Government, just as there was in the development of the American West. And we point out that we need, first of all, to have a Government program that people have confidence in, that they understand, that there will indeed be low cost access to space.

And as we sit here today, the communications satellite industry, of which we are so tremendously proud as a great achievement, really doesn't know whether the Government is going to agree, to continue, to take communications satellites up on the space shuttle or not. This is still under debate. We still don't know whether or not there is going to be a fourth orbiter. We don't know what the future of the ELV's are going to be. And I think that one of the great opportunities that the Government has to encourage private investment, is to remove some of these uncertainties with a program that is laid out that the American people, and particularly the investing public, can have confidence that here's where we're going, and we welcome your participation.

And you will notice that we put great emphasis on the next generation launch vehicle, being a private investment. And we mention that for a private investment, we don't mean a Government guarantee type of thing, but that rather, the Government only contract for payload, per pound launch to orbit, and let the private sector decide how to do it. But we say that's next generation.

Mr. WALKER. Well, but you disagreed with me, and yet made my point, I think as you come around. If in fact the communications satellite industry is sitting there today, waiting for these decisions to be made by Government, what's happening is that Government can't make those decisions, because we haven't got the resources necessary to make the decision. Nobody sees where those resources are going to come from. We're totally left at the mercy then, of what the Budget Committee decides is going to be the allocation for space. And in fact, the Budget Committee has made a determination we should get less next year, than we had this year, despite the Challenger accident.

I mean, that's the realm in which we are dealing. And so the communications industry is likely to be left hanging on that. This whole plan is likely to be left at the starting gate as a result of those kinds of decisions. And what I wonder is, if that's what we're locked into, then we've got a big, big problem. This future just is never going to take place if that's what we're committed to.

And yet, if we, as a policy determination, would decide to do those things that put some access for the communications industry into place that was maybe privately derived, such as encouraging people to fly private ELV's that helps—that helped that industry, it seems to me that marshaling of those resources is more important at this point, than coming up with additional Government funds, or just as important. Because if it provides what they need, then it's just as important if—whether NASA's spending the money, or whether someone else is spending the money. But the resources as a society are the important factor. And, you know, that's what I—what I would argue is an important ingredient in all of this, is it can't wait until the middle part of the next decade, or until the turn of the century, to marshal those resources. We had

better begin doing it now or the money is simply not going to be available.

Dr. PAINE. Well, I don't think you and I are in very big disagreement here. But I would make the point that the United States, I believe, as a matter of policy, if we are indeed going to be a leader in space has to be sure that we have assured access for our military systems, for our basic national research systems, and for the civilian sector to space—that access is low cost, high reliability, and safe.

And I think the fact that we are going now into a 2-year hiatus in which we do not have this access is a very serious thing for all sectors.

So, yes, we certainly want to attract the private investment in next-generation launch vehicles. This is going to require working with the Government. And we are going to have to look at the possibility of launching military payloads this way, the scientific payloads this way, and commercial payloads. And I think that without a space policy that gives the private sector some assurance, as to where the Nation's going in space, it will be very difficult.

What we're really trying to do is reduce the risk of private investment, because the private sector knows what is going to be going on in space, and they can pick out those parts, which then, justify a private investment.

And we agree with you, everything should be done that is at all possible, even if we have some failures, to encourage this investment as soon as we can do it.

Mr. WALKER. Thank you, Mr. Chairman.

Mr. NELSON. Mr. Andrews?

Mr. BROWN. Would the gentleman yield just briefly to me?

Mr. ANDREWS. Be happy to yield.

Mr. BROWN. Mr. Chairman, I ask unanimous consent to insert a brief opening statement at the beginning of the testimony.

Mr. NELSON. OK.

Mr. ANDREWS. Thank you, Dr. Paine and other witnesses, I am delighted to have you here today. I had the honor of being a witness at one of your public forums in Houston and I just found my name in the small print back in the back of the book and I am honored to be part of the report. [Laughter.]

Mr. ANDREWS. In your report you suggest very strongly that NASA will have to have a substantial increase in our budget to meet your goals.

What does this imply for NASA as an agency in terms of growth? What are your thoughts about that, Dr. Paine?

Dr. PAINE. I think this budget question which, of course, has also touched on, and, we have discussed many times, should be put in the perspective, that our basic recommendation is not a big immediate increase in the NASA budget. Rather, what we're saying is, let's take a good hard look at where America's going in space. Let's ask the question how much it will cost, so we don't get into these over-commitments, and followed by overruns, followed by lack of performance, followed by other programs which, in our judgment, we should be doing but which, for financial reasons, then we can't do. In other words, good, solid management of our very scarce re-

sources will get us much farther in space, get us much more value for the taxpayer's dollar.

And what we are proposing, then, is that the head of NASA be directed to take a look at the direction we are talking about in our report, and then give you what are the budget implications, what would it take to implement a program like this.

We have sketched out what we think it should cost. These numbers did not come out of the air. Obviously, we discussed these very much with NASA. We discussed them also with the aerospace industry. We have tried to come up with numbers that we think are accurate. But, of course, you can't have somebody externally from a program, manage the program, and give you the planning numbers. You have to ask the person who would carry it out, how much it would take him to do it and then hold his feet to the fire after that, and make sure that he comes in within that budget.

So, we are not really talking now here a major increase immediately in the NASA budget. Rather, we're talking about the fundamental questions, what are the directions our space program should go—civilian space program. And then, second, what pace of advance will be satisfactory to this committee, to the American public. And what pace of advance will continue America's leadership on the space frontier?

Mr. ANDREWS. Well, for instance, the Commission recommends a threefold increase in NASA's base technology budget. Would you elaborate on that just a little bit? Why is that—why is it a threefold increase?

Mr. PAINE. Well, at the present time, NASA is spending 2 percent of its budget on the base technology program. I don't believe there is an industry in this country that would put its advance R&D expenditures at such a low level. But, again, Dr. Kerrebrock will reach over and grab my microphone, I am sure, if I don't give him an opportunity. We are proposing to go from 2 to 6 percent of the NASA budget. And, again, this is a precursor investment. Rather than put money right now into large new launch systems, we're saying much better to spend it on the technology that will allow us to make the right judgment in the early 1990's as to where the American investment should go.

We're not absolutely convinced that the final answer will be the aerospace plane. We think it's extremely important that we carry the Aerospace Plane Program forward through flight demonstration. We also, however, propose a parallel effort at advanced rocket systems, so that by the early 1990's we can make the judgment, when we see how successful we are with the aerospace plane as to whether that should be the investment for the future human transport, or whether a rocket system by then will look more attractive.

And that kind of investment can save you an awful lot of money in the long run.

Mr. ANDREWS. Well, of the seven basic technologies you discussed, would you—can you prioritize? Are some more important than others? Surely there are.

Dr. PAINE. Well, again I'd like to ask our MIT friend here to prioritize those. But I believe that our statement was that those seven were more or less equal but they are very different—tether technology, super high strength materials, and then technologies

such as closed ecology biospheres, technologies like robotics. It's very difficult to say which is the more important not only to the future of our space program but really to the future economic growth of this country in the next century.

Jack, would you like to take a crack at prioritizing them?

Dr. KERREBROCK. I'd be happy to comment on that subject. Let me first make a distinction between the base technologies or what is called in your budget breakout space R&T—the research and technology base—and those seven items which are highlighted in our report which we choose to call technology validation suggestions.

Now, the base technology program of NASA right now—the space R&T base is $171 million in the present budget. So, that is the thing which we have recommended should be tripled. That's not going to break the Treasury, certainly, to do that. My point is that the R&T base which is the umbrella funding under which NASA runs the center activities which are focused on basic research and development, and from which it funds its external collaborators—universities, research laboratories, and so forth, which form a very important part of the space R&T community of the United States is a small item in the budget.

It is presently too small by the measure I would like to give you which is that it doesn't make the best use of the talent, both in NASA and in that supporting community outside. There are many, many bright students, faculty, and so forth, in universities, and there are other people in small research laboratories and in large companies who would very much like to participate at NASA's R&T base program who don't, because NASA doesn't have the money to fund them.

Now in part—but one part of the answer to your question is that you don't have to expand the manpower of NASA in order to get that benefit. Now, I'm not speaking of the large systems part of NASA. I'm talking about the research part of NASA.

Now, let me characterize that activity, which is funded out of the R&T base as broad exploratory opportunity generating research. It's the kind of research in which you really don't know what's going to arise as a result of the investment that you make. It's absolutely essential to make sure that you don't miss the opportunities and, for example, have them arise overseas.

The seven technology validation items that we highlighted are the ones in which we feel that there is sufficient knowledge of the opportunities so that the country needs to move ahead and further develop those technologies to the point where they can be selected for use for program implementation if there's a decision to do so.

Those seven are—let me just list them—are the national aerospace plane technologies, which have a large component, or a significant component, anyway, in NASA, even though most of the money is coming from DoD; advance rocket technologies, which we feel are essential to the adequate, or optimum development, let's say, of the next generation of rocket launch vehicles; aerobraking for orbital transfer; closed ecosystems; electric propulsion; nuclear electric power systems, which, again, are largely supported by DoD at the present time with a small involvement from NASA; and then, finally, the tether technologies.

Mr. ANDREWS. Let me——

Dr. PAINE. Can I——

Mr. ANDREWS. Go ahead, Dr. Paine.

Dr. PAINE [continuing]. Kind of amplify. You've asked a very thought-provoking question and I'd like to make a point that in these technologies we also took the view that one of the reasons why the American public and this committee supports NASA is because we have confidence that in the long run the spin-off from the technologies of our space program will have tremendous application here on earth.

The closed ecology biosphere is certainly an example of an area that could completely revolutionize the way we approach agriculture. In our Southwest today we still use the system the pharoahs used of the large-scale canals bringing in the irrigation water.

The closed ecology biosphere is a completely different way which you truck in a load of water and then you just use it over and over again, and only have to make up what you ship out in agricultural product. A completely different understanding of all of the microflora, all of the environmental conditions that are involved in growing food would come out of this program.

So like many of the other things that we are proposing, we think would have a tremendous impact on our Nation's economy; indeed, on the world economy.

Mr. ANDREWS. Well, that's a good point. You know, we've all said at times that we get such a big boost out of the space program—on the economic side one dollar equals seven, one dollar equals five. But surely whether we know the exact dollar amount that we gain back from our investment in space—it's a large one, and worth the investment.

Per your recommendations, do you see that kind of relationship continuing, or—and is it possible that it will even be greater?

Dr. PAINE. I think we thought it would be greater. We tried to understand the economic growth of this country from 1885 to 1935, and then from 1935 to 1985, and then with that behind us, to try and understand what are the factors in the economy today that will lead to the growth that will give us the far mightier America, in our opinion, in 2035. Certainly, the application of new science and technology, new information, new knowledge, has been absolutely basic to the economic growth as well as the security of this country.

Today, when we look at the laboratories and ask ourselves, how do we compare today with the raw material which is the basic ideas and new technology that is available for the next 50 years of growth compared to where we were in 1935 or 1885? We see far more opportunities today. The whole new series of industries that are coming out of our understanding of the double helix, the basics of life, living systems, whole new engineering disciplines that will come out of that, the whole robotics, computer revolution, which is still in its infancy; the tremendous increase of communications and transportation technology that are going to greatly reduce the cost in each product of transportation and communication with, of course, great implications for worldwide competition—we see more opportunities today for growth than probably we've ever had before.

But I tend to get carried away by these things, so let me just say, Washington tends to be characterized by a community on the Hill and a community at the other end of Pennsylvania Avenue. Cambridge, MA also has this same character. Dr. Kerrebrock is characteristic of the MIT end. My friend on the right is characteristic of the Harvard end, and I'd like to ask him—he would like to comment on your question, too.

Dr. FIELD. Thank you very much, Mr. Chairman. Tom, thank you for that very skiilful introduction—not entirely accurate, I would say.

In fact, Mr. Andrews, with your permission, I would try to focus a discussion briefly on another aspect, which is that long-term nature of what we're talking about here. Naturally, I know that this committee is faced with very serious short-term concerns. But you did ask us to look at the long-term future and to take a bold vision. And I think we did do that. In fact, it's really rather remarkable the words that you find in our overall mission statement, and they are: To support human settlements beyond earth orbit. In short, to use the entire solar system, or at least the inner solar system as the natural home of mankind to expand civilization into space. That's a dramatic, bold vision. The committee signed off on that. And I think we shouldn't lose sight of that fact.

Now, I think all of us in our hearts believe that at some level. There are differences and shades of opinion as to when that should happen and how it will happen. But I think all of us are moved to buy that vision. We sought very hard to come up with a rationale, an understanding of where that drive is coming from, and is it in fact an intelligent and a rational thing to do.

In the report we do in fact offer a rationale, which is on a page right after the pioneering mission statement. I won't go into it in detail, but at that time we were really very excited by the concept that we were, if you will, writing a declaration of independence for a new civilization in space. It remains to be seen whether the people of the United States will support that. It has to do with fundamental values of where we see the future of the country and the future of the world—whether we see it as an open society, one characterized by exploration, adventure, search for a new understanding, reduction of conflict in working together to achieve new goals. And these are the kinds of things that we discuss in that rationale.

I would just suggest to you that you do look at them and consider them as a kind of philosophical background for what we are proposing. What we are proposing is truly revolutionary. And I don't think that we should lose sight of that in the discussions of the near-term issues which are, of course, equally pressing, and unexpectedly so because of the Challenger accident.

Thank you.

Dr. PAINE. Well, I think, Mr. Andrews, you see why it was the Harvard end of the community that sent us to the moon even though it was the MIT people who got us there. [Laughter.]

Mr. ANDREWS. Just one more question I'd like you to address.

As we implement your recommendations, how must the personnel of NASA change? How is—how are we going to see NASA evolve to meet this kind of commitment?

Dr. PAINE. Well, I'd like to pass that question to Dr. Sullivan, if I may—she being one of them.

Dr. SULLIVAN. I think this is where I change hats.

Mr. Andrews, I don't like to hedge on that pressing and large scope a question, but please do remember that I am but a mere employee at the Johnson Space Center and I'm not in the management chain.

I think to undertake the full range of projects of the scope that we have portrayed here over the timeframe that we have portrayed here one must expect that changes in what we now call NASA over that time would be extensive.

I would envision in the most general form of statement that they would involve I hope a variety of new and much more creative partnerships and joint endeavors between NASA as the government's means of disseminating technology and catalyzing technology, much more creative partnerships between that arm of the Government and both private sector and academia.

I am concerned about NASA as a total entity ever fully losing its own technological and engineering expertise. I think the Agency has been a very valuable stronghold for those talents in the past, and I see some—I feel some concern for all of its personnel ultimately becoming just managers of contracts and losing their expertise, their individual expertise, to add the engineering judgment and the insight directly to the process. It would in that case not be a partnership any longer, but a sort of a master/slave, or a grantor, or a reviewer sort of function. That is not the way in which I think NASA has done its best and most productive work for the Nation in the past.

Internal organization is a much more complex issue. I think as any good industrial or scientific organization must do periodically, NASA over these years in question will, of course, have to look at the bins into which it has divided itself and the sectors of activity which the Nation now sees before it and being most important before it, and respond to those changes.

I have no crystal ball. I can't tell you even what the new bins for next week will be, much less for 15 or 20 years in the future. But, again, the key there is sound management of an organization that must catalyze and guide and frame as a partner with academia and industry.

My perception of many of the presentations we had, both from the major elements of the aerospace industrial community and from what one might term the would-be entrepreneurial players in the game, is that all seem to see a very important core role for the Government in these would-be ventures.

Dr. Paine alluded to that when he used the term risk reduction. It's a very complex and very chancy and very unforgiving game, regardless of which sector you are proposing to get into. We do tend to focus on the provision of products from space, with the exception perhaps of communication services, which I think a very promising field of space service provisions, space service supply, waiting to be opened up. But, again, somebody has got to create the first markets, or be the first available customers to request those services. That seemed, in my perception, to be the role that many of these would-be players were looking to the Government to at

least catalyze, to at least initiate with some level of certainty so that they could make their risk assessments and investment decisions accordingly.

So I do see NASA as continuing to have a seminal catalytic role and a very important one through this whole timeframe, but certainly one that must be adjusted periodically to meet the new demands and the new shape of things.

Mr. ANDREWS. Great.

Thank you very much. I thank all of you very much.

Mr. NELSON. Thank you, Mr. Andrews.

Dr. Sagan, if you will come up and join us at the table. You and Dr. Paine had scheduled a press conference in 1 minute, so it's going to have to be delayed. We want to have your testimony and opportunity for members to question you as well.

Dr. Field, please stay up with us. Just take one of those chairs and move it right up.

Dr. Sagan.

STATEMENT OF DR. CARL SAGAN, DIRECTOR, LABORATORY FOR PLANETARY STUDIES, CORNELL UNIVERSITY, ITHACA, NY

Dr. SAGAN. Thank you, Mr. Chairman. Thank you, also, George, for providing such a nice, warm seat. [Laughter.]

Considering the boundary conditions and the fact that prophecy is a lost art, I think the Paine Commission has done an excellent job with this report. It is certainly a benchmark in trying to foresee a reasonably ambitious and far-sighted view of the U.S. future in space. And it has the pleasing aspect that it tends to look further into the future than the next few years, which I think is absolutely essential, especially for so future-oriented an organization as NASA. To have only short-term objectives geared to the 2-, 4-, and 6-year terms of office of Representatives, Presidents, and Senators does not permit the orderly evolution of NASA's activities.

I believe that the central missing aspect of the U.S. civilian Space Program is the absence of a long-term goal: not a capability or a machine, but a goal—a goal that's easily understood, that's future-oriented, that's widely acceptable, and if possible, something that stirs both the mind and the heart.

The goal of the Apollo Program satisfied all of those criteria. It involved a confluence of constituencies, industrial, certainly; science and technology, certainly; the military, certainly; very important political goals, and also an enormous enthusiasm from the general public.

Apollo shows that all of those constituencies can flow together to a comprehensive, easily stated goal—stated by President Kennedy in his spring 1961 speech in a single sentence: To put a man on the Moon by the end of the decade and bring him back safely. Since then, there has been nothing remotely resembling a coherent NASA goal.

I should stress that the political aspects of that decision were preeminent. They were the American response to the Bay of Pigs debacle, and the fact that the first human being to orbit the Earth happened to have a Soviet passport—which he didn't need up there.

At that time, in the spring of 1961, there had been no successful United States unmanned probes to the Moon or the planets. We had no large boosters. We were at the earliest imaginable stage in the Space Program. We had orbited unmanned and animal-inhabited vehicles and one or two humans, just barely.

Eight years later, which is a very short period of time, three Americans voyaged in Apollo 11 to the Moon. Two of them landed and all three successfully returned, as had been urged by the President, by the end of the decade.

The step from that speech to July 20, 1969 is, in my estimation, much larger than the step from today to a voyage of human beings to the surface of Mars. Technologically, in terms of confidence in what we are able to do, in terms of our understanding of the nature of the objective, in terms of management, in every conceivable respect, Mars is not nearly so large a step for us today as Apollo was for the United States in 1961.

The success of the Space Program can be judged by various criteria. One criterion which is important for many in the scientific community and for the general public are lunar and planetary missions, and they provide a very interesting perspective. In the 1960's and 1970's when the Apollo goal was dominant, there were dozens—literally dozens—of unmanned, comparatively inexpensive missions to the Moon and the planets. And the momentum carried it a little past the end of the Apollo Program in the early 1970's to Viking, which was launched in 1975; Voyager, which was launched in 1977, and a comparatively inexpensive Venus Pioneer mission in 1978.

Since 1978, the United States has not launched a single lunar and planetary probe, unmanned or manned, not one. And it looks very much as if we will finish the decade of the 1980's in that same doleful situation—there's a bare chance that in December of 1989 there might be a launch if everything goes well.

The United States has in effect opted out of the scientific exploration of the solar system. We've had great triumphs, of course, including lately, last January, the Voyager 2 encounter of the planet Uranus and its rings and its moons. But that was a mission that was first approved in something like 1970. Because it takes a long time to get to the outer solar system we are still today the beneficiaries of the wise decisions made a decade or two ago, and I hope we will continue to be. Voyager 2 is still working and is scheduled to encounter the planet Neptune and its rings and its moons in August 1989.

Now, while the United States unmanned planetary program and many, many other aspects of our space program have been on a progressive decline for the last decade or so, there has been a significant increase in the European and Japanese space programs. They have both experienced recent successes in their first interplanetary missions connected with Halley's Comet. And the Soviet Union, which, of course, started strong, started the space age in October 1957, has been steadfastly continuing. Despite various setbacks, they have had a continued source of funding and a clear set of goals. We now find that the Soviet space program has had some remarkable recent successes in the course of which they are brokering international cooperative agreements among large numbers

of nations—not just East European nations, but Western European nations as well.

There is an increased sense of openness in the Soviet space program. When I was there earlier, there was only one door to the Institute for Space Research in Moscow I could go in. There were all sorts of places in the building that were off limits. I couldn't go anywhere without an escort.

Well, this March, when we were there for the Vega encounters with Halley's Comet there was still only one door I could go in. But I could go in by myself. I could wander anywhere into the facility. I did not need an escort. The Soviets were willing not only to tell us their plans, but even to describe errors that they themselves had made in real time. There was a degree of openness which was really remarkable and probably goes with the confidence of success.

Maybe the nations that are not doing well have to keep quiet. But the nations that are doing very well can let others see what they are doing.

Now, especially now, in the American space program, in the absence of a long-term goal, what happens is that NASA field centers set their own agendas and priorities. Their functions tend to be not some overall national goal but the preservation of jobs, and the perquisites of power. People high in the hierarchy want to stay high in the hierarchy. So a whole set of subsidiary objectives become self-generated, which not only eats up money and time and talent, but can have even more undesireable implications.

Let me give an example, and this brings me to the unhappy subject of the shuttle. In the 1970's, shuttle was imposed on a reluctant military establishment as the sole—almost sole—launch vehicle for both civilian and military payloads. There were grave misgivings in the Department of Defense. But at NASA's initiative—NASA trying to find some way to preserve continuity for NASA's own programs—NASA thought up this idea, sold it to the President as a cost-saving objective, and put all of this country's launch eggs in one basket.

Another example is the space station. NASA resolutely refuses to say what the space station is for. Now, there's two ways to say this. If you ask NASA what it would do with the space station, there is an extremely long list of answers—a list as long as my arm.

But if you ask NASA: What are our objectives in space? Let's see if the space station is the best way to accomplish them—then you get no answer.

This was the experience of those of us on the OTA's space station panel. That was the one question NASA was simply unprepared to give an answer to. Why? Because there is no established goal for NASA.

If the goal is to have a space station, then you can't ask what the space station is for. All you can ask is: if you had a space station, here is what we would do with it. That is not a cost-effective approach. [Space station is a means to an unstated goal, not a goal in itself.]

It is insidious not to have a long-term goal for the space program.

A long-term goal, it seems to me, is essential for revitalizing a dispirited NASA where, in many places, morale is in shambles—not to say that NASA doesn't have significant responsibility for the shuttle tragedy.

There is a real question about keeping science and technology teams together at field centers, at universities, and even in industry. It is getting tougher to encourage the best new graduate students to devote themselves to many years of preparation for a space program which cannot promise that it will deliver. And certainly if you talk about exploration of the solar system, what are we to tell the best young students who apply about their chances of participating in some grand exploratory objectives in, let's say, the 1990's? It becomes very difficult.

This absence of a goal tends to be self-propagating. It tends to produce a serious unraveling of the American space endeavor.

At the same time, there are now other space capable nations. The number will be increasing. They are in a state of some optimism, even though, for example, Ariane is hardly a perfectly reliable launch vehicle. And the Soviets have had their share of problems, although not lately.

This provides, it seems to me, a strong motivation—once we decide what our goal is—to try to maximize the degree of international cooperation, not just in sharing costs, although that's certainly an important enough reason in an era of fiscal austerity, but also because other nations have significant technological and scientific contributions to make.

The United States is by no means anymore the sole possessor of the science and technology expertise needed to do ambitious and important space missions.

Now, there's a certain sense in which almost any goal which satisfies the criteria I mentioned before would be enormously helpful to the present drifting status of the U.S. space program.

The Paine Commission report has large numbers of goals which lead ultimately, in the second decade of the next century in their time scale, to human exploration and eventually settlement of the planet Mars.

I believe that to be not only a good long-term goal, but the optimum long-term goal for the U.S. space program and, indeed, for the world space program.

In the interest of time, Mr. Chairman, I will not go into great detail about why that's a good objective. Some of the reasons are discussed in the Paine report and some others in an article I wrote for Parade magazine, which I would like to contribute for the record, if I may. But I do want to mention one aspect of it.

There is a kind of pig-in-a-poke aspect of establishing goals far in the future that have no immediate practical benefit. Of course, planetary exploration excites the sense of adventure which most people feel, especially in a society that developed from pioneers to the extent that this society has. Most people resonate with the exploratory ideal. Nevertheless, the idea of spending large amounts of money raises the question of whether that is too much money for the anticipated return.

We have heard today about many of the positive aspects of the space program—communication satellites; on the military side, not

just treaty verification, but also reconnaissance satellites which provide an additional measure of stability beyond treaty verification; namely, that neither side is able to surprise the other in major areas. When surprises are possible, the military establishments of both sides run in paranoid directions, and so you then ratchet up the arms race. If you can see what each side is actually doing, that tends to calm the hotheads on both sides. As Lyndon Johnson said, reconnaissance satellites are, for that reason, worth their weight in gold.

In addition, we learn about our own planet by understanding others; for things as varied as the CO_2 greenhouse effect on Earth, where we can see an extended and ghastly example of it on Venus; or nuclear winter, where we can see in Martian dust storms some of the early evidence that suggested there such a thing was possible for Earth. There are real practical benefits for practical problems here on Earth from exploring other worlds.

But the idea of sending humans to Mars cannot be justified on scientific grounds, because we can explore Mars much more cheaply with robots. The justification for missions with human crews must be something more. Apollo is an example of that something more. It was cast in the context of United States-Soviet competition. The United States had something to prove, and it proved it.

The situation today is different. I think people all over the world are crying out for some indication that the United States and the Soviet Union can work together—these two nations that have accumulated 55,000 weapons of mass destruction—that they work together on behalf of the human species and the global community. A joint United States-Soviet mission to Mars with perhaps participation from other nations as well would be an example of something that could capture the imagination of the human species. If there were some greatly-to-be-hoped-for developments in the relations between the United States and the Soviet Union—either in this administration or the next—a very good way to seal that arrangement would be a joint mission to Mars.

My concluding point is that the most important missing ingredient for NASA is not technological. It's not even fiscal. It is the clear statement of a national goal which can be made, of course, with the help of Congress, but which ultimately resides in decisions made in the White House.

Thank you, Mr. Chairman.

Mr. NELSON. Thank you for a most articulate statement, Dr. Sagan. We value your testimony very much as we did last fall, just prior to our departure to Moscow. In a 2½ hour meeting with President Gromyko, of which Dr. Paine was present, members of our delegation, Mr. Walker was one of the ones that was there with us, we openly stated a number of the potential cooperative efforts.

And I used as my point of departure in my conversation with the Soviet President the Mars project, and suggested that there were a number of things that could be done. I said, first of all, a continuation of the sharing of information about that planet and Venus—at the present time, a continuation of the working groups that had been working for a number of years that were follow-ons in large part to Apollo-Soyuz.

Second, I pointed out that the Soviets were scheduling a mission to Mars for 1988 and that we had the Mars Observer project for 1990, and we could start in a sharing of data in preparation for those missions, and then once the missions were under way and during the actual mission itself.

And then—I then pointed out the next logical step—which you've set out in your statement here today—an unmanned mission where it could well be that one country could be the lander and the rover, and the other country could be the retriever and return to Earth. And all of that in preparation, then, for ultimately the mission, as you state, by the human species in a mission into the next century with the cooperation of those two countries—perhaps other countries as well.

I would just like to share with Dr. Paine—I'm not sure I've had this opportunity to share this with you personally—but in my own experience from this past January, after just absorbing this incredible view of this planet, and how beautiful and yet how fragile it looks. And in one particular scene on the night side of the Earth, in which I was all alone at the window, as our crew was asleep, seeing the entire Middle East on the night side of the Earth—and the irony of that scene being so packaged and neat in my window compared to the reality of what in fact has been, and was, occurring on the surface of the Earth.

That—I could not help but come to the conclusion that when space flight is relatively safe, that political leaders could go into space perhaps in the next century in summit meetings, making decisions of war and peace, looking at this planet in a whole new perspective than a political leader can get here on Earth, then we are bound to have some influence for good as perspectives change.

And so in light of a very far-reaching and most excellent report that the Commission has come forth with, in stretching our visions for the next 50 years, and in light of your excellent comments, Dr. Sagan, about how mankind can benefit from us continuing to be explorers, my own little bit of personal experience, I just encourage you and I thank you for your participation. And I plead for your continued participation as we try to stretch our imaginations about where this country should go in its space program and where this planet and the human race should go in this space program.

Members of the committee, any comments? Any questions of Dr. Sagan or—Mr. Walker?

Mr. WALKER. Mr. Chairman, I, too, appreciate the testimony of Dr. Sagan and, of course, all the people that have participated today. But let me tell you one concern I have, though, when we start setting goals—and I think you defined it very well when you talked about the Apollo goal. Having met the goal, we had nothing. We had no follow-on. We—once met the goal, the program was for many people finished. And that concerns me.

I think you've got to have goals that you work toward. I think that that makes some sense. I think, though, that it also is important that as we move toward each goal we do stretch it out a little bit further. Because it seems to me one of our great problems in defining a Mars mission as being the goal right now is the fact that the American people today intuitively understand that space is important to them, but have focused all of their attention on the fact

that we went to the moon, we did it, and now there's nothing else that needs to be done.

And I think that's turned out to be a great mistake. That there was no followthrough, that we did not exploit that which we had done. And as a result, there's a very, very difficult political question that has to be addressed, and that is the next goal that we set for what purpose. Because the American people, beyond the fact that we did it, it was great as a country, and we all celebrate in it, the main thing that the American people use it for right now is to say every time you bring up some problem that we've got is: Well, if we can go to the Moon, why can't we solve that one?

That's one of the things that's basically come out of this and we've got to convince people politically that these goals mean more than simply having done it and then abandoned it.

Mr. SAGAN. Well, it depends—I entirely agree with you, it depends very much on the nature of the goal. The nature of the Apollo Program goal was, as I said, put a guy there, bring him back—then it's over.

Maybe that was precisely the right time scale and degree of specificity for the political problems that the United States was trying to solve in 1961, but it certainly has the consequences that you have mentioned. A clear indication that, for example, understanding the Moon wasn't our objective, is the fact that the last man to land on the Moon was the first scientist. As soon as scientists landed it was clearly time to stop. [Laughter.]

But now, imagine instead, a goal of not just a mission to Mars, but a self-sustaining human community on Mars. That's something which has a sweep into the future, which is not going to be quickly satisfied. It seems to me there's a problem: Too short-term a goal runs into the problem that you're talking about, but too long-term a goal puts it so far out of reach that there's nothing that prods what we're doing today.

So what is needed is a sliding scale of goals at the right intermediate position in time—not too close, not too far. Mars, to my mind, does precisely that.

One other remark I would make is that a lot of people were disappointed about the Moon. I mean, beyond the technological excitement and amazement that humans were able to walk on the Moon—and I know some of my colleagues in lunar studies will not agree with me—the Moon is fundamentally dull. If Mars had been in orbit around the Earth and that's where we had gone, the Apollo Program would not have ceased—a dynamic world with weather, climate, enormous volcanos, ancient river valleys, and continuing debates on the possibility of life there. We would still be exploring Mars if that had been our objective.

Dr. Sullivan also wanted to respond, Congressman Walker, to your question.

Dr. SULLIVAN. Mr. Walker, as we mentioned at the outset of our presentation, we did also undertake a series of 15 public hearings or forums around the country. And although I for one would scarcely presume to claim that what we achieved in that endeavor was a scientific sampling of the full range or depth of U.S. public opinion on these sorts of issues, I would submit that the overwhelming response that we did get from the people who we did

speak to, both those that we invited as known representatives of space interests in the communities we visited and those who came of their own accord, is in fact rather counter to the perception that you voiced of a disheartening sort of, well, we did it and so now what.

I would—I am the record holder for how many of these I went to? Or tied for second place for how many I had the pleasure of helping out on. There was a very clear trend amongst all the commentary that I heard at any rate, that it was recognized that Apollo had a limited objective and it had stopped. And the corollary or the follow-on to that in the minds of the people who spoke to us was that that was too bad and they wanted to do something else, and do something different and not let it stop. They did want to go on. It was not a broken bubble—a burst bubble sort of perception.

But if anything, a goal to continue on to the next step to realize that that had been a limited and short objective and we had done that, and there now were other objectives, and they were longer term. There was this outward—permanently outward bound imperative, if you will, that Dr. Field elaborated upon so eloquently.

So, I sensed rather quite a strong support for these longer term continuing and permanent goals of civilization having a frontier in the solar system.

Mr. WALKER. Well, I thank you for that. And I think that there is a very strong sentiment in the country for that. I would remind you, however, that every bit of polling data I've ever seen where they ask the question: Where is one of the areas that you'd be willing to cut in the budget? One of the areas that is always topmost or one of the top—foreign aid is always first—but one of the highest levels of participation of people saying that they wanted to cut an area is space. Because they have not yet perceived it to be something which affects them daily. I mean, it's—one area they don't want to cut, they always want to increase is Social Security, because that it affects them directly.

But that's—there are some problems out there with the general public. And what I'm saying is that the goal had better be something that's defined in a way that if you are going to sustain it politically that it is—that is meaningful to a broad base of the public. And it has to be more than an adventure. And it has to be more than even a moral imperative.

I would suggest that if Queen Isabella had to justify Christopher Columbus' trip to—to the New World on the basis of an adventure, she probably couldn't have gotten the funding even within her own court for that. She justified it on the basis that they were going to—they were going to find a short route to the West Indies and all get rich. She turned out to be wrong. But the bottom line was that that was the justification.

The same thing with the formation of the Jamestown Colony. Had the James River Co. justified it on the basis that we're going—we're going to send all these people over there and it's going to cost you a lot of money, and we're going to go and it's going to be a great adventure, there wouldn't have been much money for it. But the idea was that somebody was going to get rich out of the thing.

Somewhere along the line we have got to make this meaningful in the lives of a lot of people out there who have to sustain it politi-

cally. And I am not certain that we have done that up until this time.

Now we did it with the Apollo Program in large part because as Dr. Sagan has eloquently pointed out, we convinced the American people that we needed to do it because of the Bay of Pigs and a whole series of things. It fit with the American psyche at that moment. We have got to find a similar fit with the American psyche in order to—to move this forward in a kind of aggressive way that the Commission envisions.

Thank you, Mr. Chairman.

Mr. NELSON. Might I respond?

I think that the polling data recently would show that there is a new excitement among the imagination of the people about the space program.

Are you quoting data that is several years old?

Mr. WALKER. No, I'm quoting data which is within the last year. But I would agree with you, that when they've polled the American people—for instance, do you want a recommitment to the space program in wake of the *Challenger,* and so on, and all of that. Yeah, the American people are responding to that.

But the point is that the data I'm talking about is: What would you be willing to cut if we have to cut massively in the budget? And poll after poll after poll has shown space the—very, very high up on what people are willing to cut. And what I'm saying is, that's what we've got to overcome if you are going to sustain any kind of an effort which is anywhere close to the kind of commitment we've got to make in order to do all of this.

Mr. NELSON. I haven't seen that data. I would—my instinct tells me that it would be a different thing. But, nevertheless, Mr. Walker, you bring out an enormously important point—that if we have a goal, what do you do to sustain yourself going to that goal. How do you get people to understand the practical application of space here on Earth? And the commercialization is one way of doing it.

The cancer research, the electrophoresis, the new materials of the future, is one way. The PIMS that they are going to implant in the body cavity at Johns Hopkins are all spinoffs from space technology are practical applications. And telling that story is one way of helping the American people understand what the practical benefits are.

Dr. Sagan, you had a comment.

Dr. SAGAN. In response to what Congressman Walker was just saying, I can think of some other historical examples. Isabella not only was motivated by making money by going to the Indies but also, at least as much, by converting the heathen. And while we may quarrel today about whether that was a proper goal or not, that could be called—at least in her terms—a moral imperative. So moral imperatives have had some role.

On the issue of having to convince the public, I can think of lots of recent examples where the public isn't convinced, and the Government goes ahead anyway. [Laughter.]

Star wars is an excellent example.

Mr. WALKER. Yeah, but—allow me to interrupt on that.

Dr. SAGAN. Yes.

Mr. WALKER. You are talking about sustaining a 50-year program. You are talking about a program that has to have political input and you have to have a majority of Congressmen supporting it to a very, very substantial level of commitment over a period of years.

Dr. SAGAN. Sure.

Mr. WALKER. I would agree with you. There are many times when the Government goes totally in a different direction than the public. They do not usually do it, though, on things where they have to have a long-term kind of commitment because it's—it's impossible to do that way.

Dr. SAGAN. But star wars is a long-term commitment. And in opinion poll after opinion poll——

Mr. WALKER. Well, I used this polling data to show that—that there's a fairly substantial percentage of the public that supports star wars too.

Dr. SAGAN. Fairly substantial, but not a majority. I give you another example—the nuclear freeze is repeatedly supported by 75 to 80 percent of the American people. Somehow that doesn't propel Congress. So, it——

Mr. WALKER. Well, because it depends on how you ask those questions. If you ask a stars war question in a particular way, you can get about an 80 percent support level for it. So it depends upon how you ask those questions, and I don't——

Dr. SAGAN. Sure. If you say, do you realize the United States is utterly undefended against a Soviet attack? Do you want us to have a little defense? Most people say yes.

If you phrase the question: It will cost a trillion dollars to have a star wars system and most scientists think it won't work; are you in favor of it? Most people say no. A lot depends on how the question is asked.

Mr. WALKER. And I posed the—if I pose the question it's going to cost us $750 billion of taxpayer money to implement this program. Are you for it? You won't find very much support out there.

Dr. SAGAN. Absolutely right. Therefore, the conclusion is that polls which merely say do you want to support or not support space, are not carefully enough designed. We need a more finely detailed questioning. Since space covers a whole lot of territory.

Mr. WALKER. Well, all I'm saying to you is when you sit people down and ask them where it is they are willing to have money subtracted. The polling data indicates that this is one area where they are willing to have it subtracted. That will not be true in any area where they have some feel for a personal sense of commitment to it. And that's simply the point that I'm making, is you've got to give them.

My guess is, is that would not have shown up that way during the Apollo program in the 1960's.

Dr. SAGAN. That's right.

Mr. WALKER. It does show up that way now. The point that I'm trying to make out of all of this is, you have got to then have a goal that the American people see as being a real goal and something that has direct application to them or we will not be able to have the political will necessary in this country to sustain that commitment over the long term. And my guess is at the present

time, we've got a long way to go to establish that sense of political will.

Dr. SAGAN. The $750 billion that this might cost can be taken out of the 1 trillion that star wars will cost, and then we have another $250 billion left over for Social Security. [Laughter.]

Mr. WALKER. And we will have failed to build some of the infrastructure that star wars is going to build for us that might well help in this program. I mean, again, there's a blend between the two.

It seems to me that a lot of the money that you're ending up spending on star wars could well be the kinds of things which will have spinoff applications into other areas. For example, the aerospace plane is largely being driven—and the funding for it is being driven right now because we need a low-cost vehicle to orbit if you're ever going to deploy star wars. And so a lot of the money that's going into the development of aerospace plane is coming out of the Defense Department right now because they feel that's a very important technology.

There's enough stress in here on aerospace plane that it seems to me that that is an important part and it's largely being driven by star wars. So that trillion-dollar commitment to star wars is going to have some applications too.

Mr. NELSON. Dr. Paine, before we take your comment, which I want to hear, I also want you to clear up for the record what in fact this says about the cost of this program for the next 50 years, and put that in perspective, please.

Dr. PAINE. Let me put that in perspective. But I think also that it is relevant to Congressman Walker's statement—let me just say, that with Kathy Sullivan, I also went around the country and talked to a lot of people. And we were very impressed with the number of young people that came out to testify in our open forums.

We got, as Kathy mentioned, a very large degree of support. And I would suggest to Congressman Walker that it is quite possible that the American people are out in front of their political leadership in Washington. I think that the way in which you ask these questions is clearly a very important part of it. I think also that there is, however, a role of national leadership.

The American people didn't tell President Kennedy that the lunar program to give America preeminence in space was something that they would all vote for. There was an element of leadership in President Kennedy taking that on, announcing it, he came up before a joint session of Congress. Everybody in Congress cheered. It was widely accepted. But there was a leader in the loop. And I think that at the present time we very definitely need some leadership to help to focus where the American space program should be going.

My guess is that if a bold American space program that will continue American leadership in the space frontier is proposed to the American people, by far the majority will back that, providing that the cost is kept at an acceptable level, which gets to your other question.

In our look at what was a suitable amount of tax, if you like, for all the previous exploration, for all the previous science and tech-

nology, which has brought us to become the most technologically advanced and the most affluent Nation in the history of the world, with tremendous prospects for moving forward from our present $14,000 per capita income reasonably broadly distributed, although clearly both those things will be improved as we move to the future—we became convinced that a fraction of a percent of the national effort devoted to advancing the frontier of both science, technology, as well as human exploration, was a very reasonable level of expenditure.

As we looked at the prospects for continuing economic growth of the American economy, as I mentioned before, we were very impressed that the Nation has never had better prospects despite a large amount of hue and cry that our children won't live as well as we do. If they don't, it will be damn well because we didn't make the proper management efforts and investments that will allow them indeed to live far better than we would.

We believe that moving NASA forward at the same level of growth as the gross national product and moving the expenditures on this frontier—and really, it's an investment more than an expenditure—to half the level of Apollo, was a reasonably good judgment for planning purposes to allow us to come before you with a program that would not only lay out the direction but also the pace of advance.

And I would submit to you that it certainly is a reasonable level to begin the process. We, however, did not regard this as the final statement. We rather regarded this as something we could put before the American people through the mechanism of our report, through the mechanism of our TV report, and try to stimulate a national debate led by the leaders in Washington. And that's what we hope will happen. And I for one am quite confident that when that debate takes place you will find a very degree—a great degree of support in the American people and, indeed, almost a question: Well, why haven't you come before us before with such a program?

Mr. NELSON. Your bench mark was a half a percent of GNP. It was not a dollar figure that has been widely reported in the press.

Dr. PAINE. That's right.

Mr. NELSON. That was an erroneous report——

Dr. PAINE. Yes.

Mr. NELSON [continuing]. Attributed to your Commission.

Dr. PAINE. And that we at no place mention $750 billion. If you would take the output of the Ford Motor Co. for the same period of time, you would find it somewhat larger than that. It—when you multiply numbers by 50 that you are growing on an exponential growth, you get some very large numbers, indeed.

I don't think that should cloud the judgment.

Mr. NELSON. Anybody else from the Commission like to comment? Anybody from the committee? Any of the staff?

Well, it's been a stimulating morning. We have—we have blown your schedule on your press conference. You are now 46 minutes late for your press conference. Do you all want to have it right here?

Dr. PAINE. It's Carl's press conference.

Mr. SAGAN. We are set up in the other room, Congressman Nelson. Thank you, though, for the invitation.

Dr. PAINE. Congressman Nelson, I think I can speak for all 15 Commissioners and for our very hard working and talented staff when I say we are very grateful to this committee for having asked us to conduct this study.

Mr. NELSON. We are just delighted, Dr. Paine. Excellent morning, excellent report. We hope now that the decisionmakers can execute on this vision that you have painted for us.

Thank you, and the meeting is adjourned.

[Whereupon, at 1:15 p.m., the subcommittee adjourned, to reconvene subject to the call of the Chair.]

THE HONORABLE MANUEL LUNJAN, JR.
OPENING STATMENT
JULY 22, 1986

MR. CHAIRMAN, I JOIN YOU IN WELCOMING TODAY'S PANEL OF WITNESSES. THIS COMMITTEE ASKED FOR A LONG-RANGE VISION OF OUR NATION'S FUTURE IN SPACE AND THAT'S JUST WHAT WE GOT. PERSONALLY I AM VERY PLEASED WITH THIS REPORT.

I ALSO WANT TO TAKE THIS OPPORTUNITY TO COMMEND DR. PAINE AND EACH OF THE COMMISSIONERS AND STAFF ON A JOB WELL DONE. I AM PLEASED THAT WE WILL RECLAIM YOUR EXECUTIVE DIRECTOR, MARCIA SMITH FOR OUR OWN USE. WE REALLY DO MISS HER WORK AT THE CONGRESSIONAL RESEARCH SERVICE AND WILL BE GLAD TO HAVE HER BACK.

IT IS UNFORTUNATE THAT THE CHALLENGER TRAGEDY AND THE ROGERS COMMISSION INVESTIGATION HAVE CAST A LONG SHADOW OVER YOUR REPORT. WHILE IT IS NOT CLEAR THAT THE CHALLENGER ACCIDENT WILL HAVE A LONG-TERM IMPACT ON THE SUCCESSFUL IMPLEMENTATION OF YOUR RECOMMENDATIONS, IT IS CLEAR THAT THE ACCIDENT HAS SHIFTED THE NATION'S FOCUS OF CONCERN FROM THE FUTURE TO THE PRESENT. THIS TIMING IS UNFORTUNATE, AND IT MAKES YOUR JOB EVEN HARDER.

I ENCOURAGE YOU AND YOUR COLLEAGUES TO CONTINUE TO PRESS FOR THE IMPLEMENTATION OF THE RECOMMENDATIONS CONTAINED IN YOUR REPORT. WHILE IT IS CERTAINLY DIFFICULT

FOR THE CONGRESS AND NASA TO FOCUS ON PLANS FOR THE FUTURE WHEN OUR CURRENT SPACE PROGRAM IS IN DISARRAY, NONETHELESS WE MUST PLAN FOR OUR NATION'S FUTURE IN SPACE.

FOR MY PART, I WILL ENCOURAGE DR. FLETCHER TO REVIEW YOUR REPORT THOUGHTFULLY AND WITH GREAT CARE. I WILL FURTHER ENCOURAGE HIM TO COME UP WITH A PLAN TO IMPLEMENT SPECIFIC RECOMMENDATIONS CONTAINED IN YOUR REPORT. AS AN EX-OFFICIO MEMBER OF YOUR COMMISSION, I HAVE REVIEWED BOTH THE COMMISSION'S METHODOLOGY AND CONCLUSIONS AND FOUND THEM BOTH TO BE FUNDAMENTALLY SOUND. I LOOK FORWARD TO HEARING TODAY'S TESTIMONY, ESPECIALLY AS IT PERTAINS TO THE PROJECTED COST OF THIS INNOVATIVE PROGRAM.

FOR ME, THE BOTTOM LINE IS THAT WE CANNOT AFFORD **NOT** TO INVEST IN NATION'S FUTURE IN SPACE.

THANK YOU VERY MUCH.

GEORGE E. BROWN, JR.
REMARKS BEFORE THE SUBCOMMITTEE ON
SPACE SCIENCE AND APPLICATIONS
HEARING ON REPORT OF THE
NATIONAL COMMISSION ON SPACE
JULY 22, 1986

Mr. Chairman, today we will be discussing the report of the National Commission on Space. I believe that the recommendations set forth in the Paine Commission report is just what the American space program needs at this critical juncture in its existence.

The congressionally-mandated, presidentially-appointed National Commission on Space was created to study existing and proposed space activities and formulate an aggressive civilian space agenda to take America into the 21st century. In the spring of last year, the President appointed a 15-member blue-ribbon commission, headed by former NASA administrator Dr. Thomas O. Paine, whom we have the distinct honor of hearing testimony from today.

In the whirlwind of debate and controversy surrounding the tragic loss of the Space Shuttle Challenger, the report of the National Commission on Space is like a fresh breeze. The finding and recommendations of the Paine Commission are included in an illustrated report entitled, "Pioneering the Space Frontier: The Next Fifty Years in Space." I strongly urge any of my colleagues who have not yet read this document to do so.

As we rebuild NASA out of the ashes of the Challenger tragedy, we must establish a clear set of national space goals, and a strategy for achieving those goals. To this end, the Administation and Congress need look no further than the Paine Commission report.

The Paine Commission report is a triumph of vision and boldness. The commissioners set their sights beyond the immediate difficulties at NASA. The Commission envisions thousands of people living and working on the Moon, on Mars, and in spaceports throughout the solar system. In a sense, these ideas are radical, but I believe that the Paine Commission has taken a rational approach to formulating their agenda.

It is difficult to conceive of these advances in our current political and economic environment. But fifty years ago, today's space achievements were inconcievable also. To accept the

challenge of the Paine Commission will take a long-term commitment by the American people. Reaching out to meet the challenge of the next frontier will take the resources and determination of a generation or more.

Adopting these ideas, however, will not translate into an inflated NASA budget in FY 1987. The Paine Commission suggests a steady low-level, but significant increase in funding for NASA over the next five years. In fact, the level of steady funding necessary to achieve the goals of the Paine Commission would only be about half the NASA budget during the height of the Apollo program.

Mr. Chairman, I strongly urge my colleagues to consider favorably the recommendation and findings in the Paine Commission report. We may not all agree on all aspects of the report, but it is good starting point. With this report as a base, Congress and the President can begin preparing the necessary space policy to take this nation into the 21st Century.

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